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Paris, 1889

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ELECTRICITY

AT THE

PARIS EXPOSITION
OF 1889.

BY

CARL HERING.

*FORMING A PORTION OF VOLUME IV OF THE REPORTS OF
THE UNITED STATES COMMISSIONERS TO THE
UNIVERSAL EXPOSITION OF 1889
AT PARIS.*

THE W. J. JOHNSTON COMPANY, LTD.,
41 PARK ROW (TIMES BUILDING), NEW YORK.
1893.

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PREFACE.

THE official report on the electrical features of the Paris Universal Exposition of 1889 is included among a large number of reports by United States Commissioners to the various departments of the Exposition, and the whole has just been published collectively by the Government.

Owing to the very many groups and classes comprised, the publication is not only cumbersome in form, but inconvenient for ready reference and use, and as its circulation will probably be confined chiefly to public and other large libraries, the work will not be readily obtainable by those who desire copies.

In offering this volume to the public, the publishers endeavor to meet the wishes of those to whom the collection of official reports will not be accessible, or who desire the complete portion on electricity in a convenient form for reading and reference.

Although ready for the press three years ago, this volume could not be published until after the publication of the complete report; most of the matter, however, is of a technical character not affected by the delay.

The present volume contains all that portion of the complete report which refers to the department of Electricity, including an account of the work done by the International Congress of Electricians held at the time of the Exposition. The edition is limited to a small number of copies.

October, 1893.

REPORT

ON

ELECTRICITY

(CLASS 62),

BY

CARL HERING.

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REPORT ON ELECTRICITY.

By CARL HERING.

In the following report the writer has endeavored to give a general description of the more important exhibits, accompanied by comparisons, opinions, histories of their development, summaries of the progress shown, statistics, and in general such information as will indicate the extent and importance of this class at the exhibition, and the present state of the art as represented by this exhibition.

This being the first universal international exhibition held since the practical beginning of the development of this great industry, it was of interest to notice the place it took among other industries, and the part it played in making the exhibition attractive and instructive. Owing to the absence of exhibits from a number of different countries, the exhibition in this class was not as international as might have been desired, though the number of foreign exhibits was by no means small. For this reason the exhibits cannot be said to represent the true state of the art, except in such branches in which the French excel. The industry was, however, very well represented, and, as far as France was concerned, it was very complete. In general it was quite large, very interesting, and instructive.

It was to be regretted, for several reasons, that this industry, which in the United States ranks among the largest of the country, did not receive the prominent place in the grouping of the exhibits that it demands. In grouping it, the same classification was adopted as in the exhibition of 1878, when it may be said to have hardly commenced its development. The present importance of this industry demands that it should be made a separate group, in order that it may receive the attention and prominence which it deserves. It is strongly urged that in future exhibitions the old classification should be altered, giving this subject the rank of a group instead of a class.

EXTENT AND RELATIVE IMPORTANCE OF THE EXHIBITS FROM DIFFERENT COUNTRIES.

The following compilations will give an approximate idea of the relative importance and extent of the exhibits from the United States in this class, as compared with those from other countries.

The number of exhibitors in this class were as follows:

France, about	360
United States	28
Great Britain	19
Belgium	13
Switzerland	8
Russia	5
Portugal	4
Austria	3
Mexico	3
Italy	2
Chile	2
Uruguay	2
Germany	1
Japan	1
Luxemburg	1
Norway	1
Finland	1
Argentine Confederation	1
Total	455

In a total of 455, France had 360, leaving 95 foreign exhibitors. Of these the United States had 28, which is therefore about one-third of all the foreign exhibits. England comes next, having one-fifth. France had 79 per cent of the total number of exhibitors; United States, 6.2; Great Britain, 4.2; Belgium, 2.8; Switzerland, 1.8; Russia, 1, and the rest together, 5 per cent. It is to be regretted very much that Germany was practically not represented in this class at the exhibition .

Of the fifteen members of the electrical jury, France had 10; United States, 2; Great Britain, 1; Switzerland, 1; Belgium, 1. Besides this, there were 5 supplemental jurors: France had 3, Great Britain and Belgium, each 1.

The floor space occupied by our electrical exhibits was 967.25 square meters, or, in round numbers, about 1,000 square meters. That of the French section was about 2,000 square meters, not including the eight or ten stations distributed about the grounds for lighting. The floor space occupied by the other foreign countries can not be determined with accuracy, owing to the fact that the exhibits were together with numerous others, and were very much scattered about the grounds. From an estimate, however, it appears that Switzerland comes next, with 210 square meters, then Belgium and then Great Britain, with 60 square meters, the others being quite small. The space occupied by the United States was somewhat greater than that of all the other foreign countries combined. However, the importance of an exhibit is by no means proportional to the space it occupies. Neither will the number of exhibitors represent the importance of an exhibit. These figures merely give an approximate idea of the extent of our exhibits as compared with that from other countries.

A better comparison of the real values of the exhibits may perhaps be had from the number and nature of the awards made by the jury, as that eliminates entirely the space occupied, and in a measure also the number of insignificant exhibitors. The awards made by the jury were as follows, in order of their value: Grand prize, gold medal, silver medal, bronze medal, and honorable mention. Now, the mere total number of awards given to the different countries would by no means represent the value or importance of the exhibits from those countries. It is absolutely necessary, if any summation at all is to be made, to give the different awards some definite relative values. Such a relative scale is difficult to determine upon, as it is almost entirely a matter of opinion. Different persons have entirely different views regarding it, depending on what award they received or did not receive, as well as on the award which their neighbor received. It is certain, however, that an arithmetic scale of relative values of 5, 4, 3, 2, 1 does not express the relative values of the different awards. The importance of the higher awards increases much more rapidly. A geometric scale would give much truer values, and therefore the following scale will be assumed here as representing a fair average value: Grand prize, 20; gold, 10; silver, 5; bronze, 2; honorable mention, 1. By multiplying the number of the awards by their respective values on this basis, the totals obtained can then be assumed to give their relative values.

The awards made to electrical exhibitors in the different countries, and their relative values on this basis, were as follows:

	Order of succession.	Grand prize.	Gold medal.	Silver medal.	Bronze medal.	Honorable mention.	Total relative values.	Total relative values in percentage.	Percentage of number of exhibitors.
France	1	6	30	48	58	67	843	65.2	79
United States	2	4	6	4	2	2	166	12.8	6.2
Great Britain	3	1	4	4	3	2	88	6.7	4.2
Belgium	4		5	3	2	1	70	5.4	2.8
Switzerland	5	1	3	2	2	1	65	5	1.8
Russia	6		2		2	1	25	1.9	1
Germany	7		1				10	3	5
Luxemburg	8		1				10		
Japan	9			1			5		
Uruguay	10				2		4		
Italy	11				1	1	3		
Finland	12				1		2		
Austria	13					1	1		
Portugal	14					1	1		
Norway	15					1	1		
Total		12	52	62	73	78	1,294	100	100

It will be seen also from the above that the United States has one-fifth as much as France, twice as much as England, and about two and a half times as much as Switzerland and Belgium. It has four times as many grand prizes as any other foreign country, more gold medals and as many silver as any other. It received one-third of all the grand prizes, and about 12 per cent of all the gold medals.

As far as awards are concerned, there were nineteen exhibits from the United States. Eighteen of these, or 95 per cent, were awarded as in the above table, 21 per cent received grand prizes, 32 per cent gold medals, and 21 per cent silver medals.

The awards were as follows (in alphabetical order):

Grand prize: American Bell Telephone Company, Edison, Elihu Thomson, Elisha Gray.

Gold medals: American Graphophone Company, Cobb Vulcanite Wire Company, Heisler Electric Light Company, Okonite Company, Sprague Electric Railway and Motor Company, Western Electric Company.

Silver medals: Commercial Cable Company, Consolidated Telegraph and Electrical Subway Company, Elektron Manufacturing Company, Sperry Electric Company.

Bronze medals: Electrical Supply Company, Solar Carbon Company.

Honorable mention: American Nickel Works (Wharton), Munson Lighting Conductor Company.

Some idea as to the importance of the electrical exhibits, in comparison with the other exhibits from the United States, may be had from the number of grand prizes awarded in the other classes. There were in all fifty-three grand prizes awarded to United States exhibits; four of these, or 7.6 per cent, were for electrical exhibits. One class received nine; two classes, four; one class, three; five classes, two; twenty-three classes, one. But this is not a fair comparison, as twenty-seven (over half) of the grand prizes were for public institutions and government exhibits. Eliminating these, there remain twenty-six grand prizes to companies, manufacturers, and inventors. Out of these, electricity was the only class receiving four, or 15.4 per cent. Four other classes received two each and fourteen classes one each.

Among the great successful inventions in the practical application of electricity, the United States may claim the telegraph, the telephone, the incandescent light, and unquestionably the microphone* also; France, the accumulator and the Gramme ring; Italy, the battery and the Pacinotti ring; England, the self-exciting dynamo; Germany, the drum armature; Russia, the commercial arc lamp.

PROGRESS.

One of the objects of a report of this kind is to give a summary of the progress made in this industry and science since the last international exhibition, taking as the present state of the art that represented by the present exhibition. In this particular class, however, this would be difficult and unsatisfactory for numerous reasons. If the International Electrical Exhibition at Philadelphia in 1884 is taken as the last exhibition prior to this, it would not give a basis for the progress made in Europe, as this exhibition was international in name only; there were scarcely half a dozen foreign exhibits. If the electrical exhibition at Vienna in 1883 be taken it would not include America, as that exhibition was almost exclusively European. The development of the greater part of this great industry has been so recent that to go back farther than the Vienna Exhibition is to go back to the beginning. The last universal exhibition of 1878, in Paris, which is really the one which should be taken in such a comparative report, is too early for such a comparative report in this branch; the state of the industry at that time may be said to be limited to telegraphy, batteries, bells, electroplating, and a few dynamos. It may therefore be said that by far the greater part of the present large industry has developed since that exhibition.

---

* Although Hughes made the invention in England, he had lived the greater part of his life in the United States and had obtained his whole education here, which led him to the invention.

Just about that time, however, and within a few years later, the telephone, the microphone, the arc light, the incandescent light, the practical systems of distribution of light, the accumulator, and other fundamental inventions, forming the present industry, began to come into use; this date may therefore be taken as representing about the time of the birth of the present large industry. A summary of the progress made since that exhibition is therefore simply a record of the present state of the art as shown by this exhibition, as almost all that has been done has been done since that date, excepting the few subjects mentioned above, which comprised the whole industry at that date. There are few, if any, industries of the extent of the present electrical industries that have made such wonderful progress in so short a time, not much over ten years.

As this class includes so many different branches, it was thought preferable to give short histories of their development in connection with the descriptive reports of each branch, rather than to attempt to summarize them here.

The present state of the art cannot be said to have been fully represented at this exhibition. Germany, Italy, and Austria, where much has been and is being done in this field, were very poorly represented, in fact were practically not represented at all. The exhibits from England, though very good, did not represent the great progress made there. From United States too, some important branches were not represented. Political prejudices unfortunately kept away many interesting exhibits—chiefly from Germany.

In France great progress has been made in telephony and telegraphy; in the former, because there are no fundamental patents to hinder progress, in the latter because it is under Government control. In electric lighting, however, progress has been very much hindered, in Paris at least, by the Government. In Paris the city government has granted to a syndicate a monopoly for the supply of gas; it receives in return one-half of the profits above 5 per cent. This income to the city last year was stated to be 12,000,000 francs (about $2.400,000). This makes it very much to the interest of the city to keep out as much as possible the competing electric light. As it can not, in the interests of justice, keep it out altogether, it has enacted laws, which, though not prohibitory, at least hinder its introduction very greatly. The municipal tax on a ton of coal in Paris is 1.20 francs (24 cents) for commercial purposes and 7.50 francs ($1.45) for private use. Electric lighting companies, however, have to pay the *latter* tax and not that for commercial purposes. If they place the stations outside of Paris and lead the current into the city, the energy is measured and taxed in proportion to the equivalent in coal. An authority states that his electric company must pay 5 per cent of their receipts (not profits) to the city for a station in the city, and 7 per cent when it is outside of the city. The charges of one of the companies are from 21 to 29 cents per kilowatt hour, which is about 16 to 21 cents per horse power of current; in Philadelphia, for instance, it is 7 cents per horse-power hour. The cost of gas in Paris is 30 centimes per cubic meter for the citizens and 15 for public lighting; this is equal to $1.64 and 82 cents per thousand feet. The latter is also the average cost in the provinces.

It was intended to include in this report statistics regarding the present extent of the industry; but in general this had to be abandoned as it was found impossible to obtain this information for the foreign countries; a few statistics regarding the extent of the electric light industry are, however, given in connection with that subject. The following general figures may be of interest here. The Proceedings of the Electric Light Association gives the following figures for the United States for the beginning of 1890: 2,700,000 incandescent lamps, 230,000 arc lamps, 500.000 horse power used for lighting; over 600 miles of electrical railroads completed and in construction; 750,000 miles of telegraph lines; over 120.000 miles of telephone lines. The following for the beginning of 1890 is taken from the Electric World:

> The number of electric lighting companies in the United States and Canada operating central stations at the beginning of 1886 was 450. This number had increased at the beginning of 1887 to 750, at the beginning of 1889 to nearly 1.200, and at the beginning of 1890 to 1,277, including 25 in Mexico and Central America. Meantime 266 gas companies had engaged in electric lighting, so that the total number of companies engaged in electric lighting at present (1890) is 1,543 The number of isolated or private incandescent and arc light plants at the beginning of 1887 was about 1,000 each. Now there are 3.925 private plants in the United States, 175 in Canada, and 200 in Mexico and Central America, making 4,300 in all. The

number of arc lamps in use in 1882 was 6,000. This number doubled each year for four years, and has since grown rapidly until there are now 235,000 arc lamps in use. The number of incandescent lights has increased from 525,000 in November, 1886, to 3,000,000 at present. The number of electric motors now in operation in the country is estimated at 15,000, many of them from 15 to 50 horse power. There are nearly 200 electric railways in over 125 towns and cities, and these have in operation or under contract 1,884 cars on 1,260 miles of track.

CLASSIFICATION.

The exhibits included in this class are of such a nature that a rational classification in a report of this nature becomes very difficult. Numerous systems of classification adopted in other reports were considered, but all were found unsatisfactory for one reason or another. One of the best of these was the one proposed by M. Hospitalier, in l'Electrician (May 25, 1889), in which he divides the subject into: production, transformation, transmission, measuring instruments, and the various applications, thermic, chemical, mechanical, and miscellaneous. But although rational in so far that there is no doubt as to where an exhibit belongs, it brings together subjects like electric railroads and telephony which are really widely different, though both are "mechanical applications" of electricity. It furthermore separates batteries from accumulators and both from electrochemistry. The writer has, therefore, adopted a new classification, which might be termed a "natural" one, which brings together into each one of several sections those exhibits which almost always accompany each other and can not well be separated from one another—that is to say, those which would naturally be included in the scope of a specialist in any one broad field. It has been found that the exhibits can be examined and described much more readily when divided into such natural sections. It is suggested by the writer that the classification might perhaps be the most rational subdivision of the broad class "electricity" to be used at subsequent exhibitions both for grouping and for examination, as well as for a descriptive report and for cataloguing. Such a classification divides the whole class into five principal sections and a few smaller ones which do not belong to any one of the others, or else belong equally well to several of them. The first, largest, and most important includes electric lighting, power, dynamos, etc., which for want of a better name will here be called "*electrodynamics*," as it naturally forms a department in dynamical engineering. The second one in order of importance is *telegraphy and telephony*. The third, *annunciators, bells, and miscellaneous applications*, might perhaps have been included with the second, but as it forms a distinctly separate industry it was thought best to make a separate section of it. The fourth is *electrochemistry*, and the fifth, *measuring and scientific instruments*. The remaining ones in no special order of importance ıre: (6) *thermogenerators;* (7) *wires and conduits;* (8) *medical electricity;* (9) *miscellaneous*, and (10) *general supplies.* The subdivision of these sections will be found in the index.

DESCRIPTION OF THE EXHIBITS.

In the description of the exhibits, which forms the greater part of this report, the writer has endeavored to give only brief descriptions, not burdened with details, except where such are necessary or of importance, novelty, or interest. Current literature in this branch is so good and so widespread that it may be assumed that specialists have already read descriptions better detailed than it would be possible to do in a report of this nature covering such a wide ground. The writer has therefore limited himself chiefly to giving a general summary of the chief features of the exhibits, more for the sake of comparison and as a record of the present state of the art as represented at this exhibition. Under a number of the special headings are given short summaries of the history or progress of that class of apparatus, and a summary of the latest developments exhibited. Whenever good descriptions in standard periodicals were known to the writer it was thought preferable to refer to them, and give here only short summaries of the articles, rather than to burden this report with copies of existing descriptions, which are readily accessible in any good library.

Descriptions, opinions, and comparisons have been given from the standpoint of an American, acquainted in general with American methods and systems, a general knowledge of which is assumed on the part of the reader.

It was endeavored to do justice to all exhibitors and also to inventors, by always giving the names, whenever the latter could be obtained. Also to state whenever possible the award which was given the exhibit. However, when no such award is mentioned, it does not necessarily mean that it was not important enough to receive an award. It may be that the exhibitor was not entitled to receive awards, being represented on the jury, or that the particular exhibit described was but a part of a collective exhibit for which the award was given.

It was intended to make this description as complete a summary as possible of the more important, interesting, or novel exhibits. In some cases, however, promised descriptions or references were not received; in others none could be obtained at all. In some cases the exhibits were installed too late to be catalogued, and of these some may, therefore, have escaped the writer's notice; others were classified in other classes, to which they more properly belonged, and it was, therefore, difficult to find them. In numerous cases the exhibitor feared piracy, and therefore hesitated and even sometimes declined to give detailed information—in some cases even when descriptions had been published and all that was asked for was a reference to the publication. In most cases the exhibits were not accompanied by attendants, and all the information which could therefore be obtained was from inspection, from circulars, or correspondence, or descriptions in journals, references to which were, however, difficult to obtain. The difficulty of making a description was increased by the fact that it was forbidden by the exhibition authorities to make notes or sketches; these were confiscated when found. Much of the apparatus was in cases, without either an attendant or a description or a reference to the same.

There were numerous exhibits in which electricity was applied, which, however, belong more properly to other classes, because they are included in the scope of specialists in those classes and not necessarily in the scope of the specialist in electricity. These have been referred by the writer either entirely or in part to the other classes. Among these classes are railroads (signals), meteorology, metallurgy, implements of war, engineering, clocks, medicine, surgery, physical and physiological apparatus, etc. It requires specialists in those classes and not in electricity to properly appreciate and describe such applications of electricity.

In reducing prices to dollars the value of the franc was assumed as 19.3 cents and of the pound sterling $4.84. The word "here," frequently used in this report, refers to the United States and not to France.

JURY.

The jury of awards for the class 62, electricity, consisted of fifteen active members and five associate members, who were not entitled to vote. The names are as follows:

President: Professor Mascart (France), member of the Institute; Professor of the College of France; member of the jury of the Exposition in 1878.

Vice-President: William H. Preece (Great Britain), member of the Royal Society; Chief Electrician of the State Telegraph Department.

Reporter: Prof. A. Potier (France), professor of the National High School of Mines.

Secretary: Colonel Turettini (Switzerland).

Members from France: Messrs. Marcel Deprez, Hippolyte Fontaine, Fribourg. Huet, Postel-Vinay, Gaston Sciama, Col. Sébert, Trotin.

Belgium: Prof. E. Rousseau, Professor of the University of Brussels; member of the jury at the Exposition of 1881.

United States: B. Abdank, Carl Hering.

Associate members: Jousselin, Rau, Sautter, from France; Leon Gody, from Belgium; J. Aylmer, from Great Britain.

Of the fifteen active members, five (or 33 per cent) were from foreign countries, of which the United States was the only one having two members (or 13.3 per cent) of the whole jury. Owing to the large number of exhibits and the wide range of this class, the jury subdivided itself into the following sections: (1) Machines, transformers, instruments—Fribourg, Hering, Potier, Sciama, Turettini; (2) telegraphy, telephony, signals, cables, wires—Aylmer, Jousselin, Preece, Trotin; (3) lighting and accessories—Huet, Postel-Vinay, Rau, Rousseau, Sautter; (4) electro-chemistry, batteries, accumulators, bells, miscellaneous—Abdank, Fontaine, Gody, Hering, Mascart, Sébert.

The examinations were made chiefly by the individual sections, but in many cases the visits were made by the whole jury together, as also by members individually. Awards were recommended by the sections and were discussed and voted upon by the whole jury, at which meeting all but one of the members (Deprez) were present. The examinations made by this jury extended over a period of about two months.

Official tests of many of the dynamos were made by the members of the jury. Those of accumulators, cables, a few batteries, and arc lamps were made for and under the auspices of the jury by the Labratoire Central d'Electricité. Besides these, many individual tests and examinations were made and witnessed by the members. The tests were to aid them in their work, and the results are in general not for publication.

For a comparative list of the awards in this class in the different countries and classes, see page 11.

CONGRESS.

Organization.—An official International Congress of Electricians was held in Paris from August 24 to 31, 1889. The committee of organization consisted of Prof. Mascart, president; Messrs. Lippmann, Fontaine, and Gariel, vice-presidents; three secretaries; a treasurer, and twenty-two members, all of whom were from France, and were appointed by the French administration in July, 1888. At the opening, the following officers were elected: President, Mascart; honorary president, Sir William Thomson (Great Britain); vice-presidents, Ferraris (Italy), Kareis (Austria), Potier (France), Preece (Great Britain), Rousseau (Belgium), Stoletow (Russia), Weber (Switzerland); reporter, Joubert (France); director, Carpentier (France). The work of the Congress was divided into four sections, as follows: (1) units and measures; (2) industrial applications; (3) telegraphy, telephony, and signals; (4) electrophysiology.

Membership.—There were about five hundred and thirty members who took part, eleven of whom were from the United States; there were delegates from foreign governments and societies, from Belgium, Brazil, Chile, Spain, Sandwich Islands, Greece, Italy, Japan, Mexico, and United States.

Proceedings.—A few papers had been prepared by appointment to introduce the subjects, as also a list of suggestions of various subjects to be discussed and acted upon. Each section held from four to six meetings. As a very good summary of the proceedings was published officially by the administration and may be found in public libraries, it is not considered necessary to repeat it here. Most of this summary will be found very interesting. A complete set of the papers read, and the discussions, has been published by the administration. Some of the papers may be found in the various technical journals of those dates.

Units adopted.—The most important work accomplished was the unanimous adoption at the final general session of the following units and definitions:

Joule.—The practical unit of work is the *joule*. A joule is equal to 10^7 C. G. S. units of work. It is equal to the heat disengaged during a second by an ampère through an ohm.

Watt.—The practical unit of power is the *watt*. A watt is the power of a joule per second. It is equal to 10^7 C. G. S. units of power. The Congress expresses the wish that in practice the power of all machines, mechanical as well as electrical, be expressed in *kilowatts* * (=1,000 watts) in place of horse-power.

Decimal candle.—For measuring the intensity of a light in candles, the practical unit is to be a twentieth part of the absolute standard of light defined by the International Electrical Congress of 1884: it is to be called the *decimal candle.*†

Quadrant.—The practical unit of the coefficient of induction is the *quadrant*. The quadrant is equal to 10^9 centimeters.

Period.—The *period* of an alternating current is the duration of one complete oscillation.

Frequence.—The *frequence* of an alternating current is the number of periods per second.

Mean intensity.—The *mean intensity* of an alternating current is defined by the formula:

$$C_{mean} = \frac{1}{T}\int_0^T Cdt$$

Effective intensity.—The *effective intensity* of an alternating current is the square root of the mean square of the intensity of the current.

Effective E. M. F.—The *effective electromotive force* of an alternating current is the square root of the mean square of the electromotive force.

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*One kilowatt equals 1,000 watts (as its name indicates), or 1.3592 metric horse-powers (or about four-thirds, within 2 per cent); or 1.3406 (English) horse-powers (or very nearly four-thirds, within one-half of 1 per cent). One metric horse-power equals 0.73575 kilowatt (or nearly three-fourths); one (English) horse-power equals .74594 kilowatt (or very nearly three-fourths).

†This decimal candle is very nearly equal to the English standard candle and to a tenth part of a carcel.

Apparent resistance.—The *apparent resistance* is the factor by which the effective intensity must be multiplied to give the effective electromotive force.

Accumulator plates.—In an accumulator the term *positive plate* is to indicate that one which is connected to the positive pole of a circuit during the charge and that which forms the positive pole during discharge.*

The Congress recommends, as a means to determine the degree of incandescence of a lamp, the method proposed by Mr. Crova and adopted by the second section.

The metallic circuit (double-wire circuit) is adopted for municipal telephone circuits and for lines connecting cities (interurban).

The term *interurban* is to apply to all telephonic communications between two subscribers or public stations forming parts of different groups.

The following was recommended by the section, but was not adopted by the Congress, on the grounds that it was of too administrative a character: The unit of interurban telephonic conversation is fixed as three minutes.

A communication from the American Institute of Electrical Engineers was presented through their delegates to the Congress, Messrs. Hering, Tesla, and Wetzler proposing that the next International Electrical Congress meet in the United States on the occasion of the coming International Exhibition in 1892.

CONCLUDING REMARKS.

In concluding these introductory remarks the writer can not urge too much that the very rapid growth of electrical engineering and its present great importance among the various industries, as shown by this exhibition, demand that it should hereafter receive a more prominent place in the classification and grouping of the exhibits at future exhibitions. It should, without question, be made a separate group, divided into at least two or three classes, in order that it may be given the prominence and attention which its importance demands. It is to be regretted very much that this was not done at the present exhibition, instead of retaining the old classification of 1878, at which time the application of electricity in the arts and industries was practically limited to telegraphy, batteries, and bells.

In conclusion, the writer desires to express his full appreciation and his thanks to Prof. Potier, of Paris, for his kind and valuable assistance in furnishing the writer with much valuable information, particularly regarding the French exhibits; also to Mr. B. Abdank-Abakanowicz; Prof. Mascart, of Paris; Mr. William H. Preece, of London; Dr. Palaz, of Losanne, and to the secretary of the National Telephone Company of London for important information and assistance in obtaining the same. To Mr. August Reeb, of the French Telephone Company, and to Mr. William J. Hammer, of the Edison Company, the writer is indebted for detailed information regarding their respective exhibits. Mr. J. Carpentier, of Paris, Messrs. Elliott Bros., and Messrs. Woodhouse and Rawson, of London, kindly furnish the cuts which accompany the description of their exhibits.

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* Or, in the usual lead accumulator, the brown or peroxide plate.

The writer desires also to acknowledge the kindness and courtesy of the French administration of the Exhibition.

I.—ELECTRODYNAMICS.

DYNAMOS.

GENERAL.

Historical.—The present commercial dynamo may be said to have been developed from experimental machines almost entirely within the past 12 or 15 years. Although the general principles were known, and the underlying inventions had been made a number of years before, yet as there was practically no great demand for dynamos they received little attention until electric lighting was begun on a commercial scale, when the demand became so great that much attention was given them. As there were no fundamental patents to hinder progress, keen competition soon developed the dynamo into a very good and efficient machine.

Progress.—Since this rapid development the progress has been slow but not unimportant; it has been mainly in the direction of finding the most advantageous proportions, rather than to find radically new forms. While the latter has been, and is, repeatedly attempted, yet most of them are abandoned for the well-studied and well-tried forms. Improvements have therefore been mainly in developing the best proportions and disposition of parts, and in details. The best machines at present are still in principle those of the original Gramme, Pacinotti, or drum armature types, though very materially changed in their proportions and in the more advantageous disposition of parts.

As is generally the case with the development of such complex mechanisms, extremes were tried in all the different proportions, until at present the dynamo may be said to have reached a high state of perfection, so that any radical improvement will have to be in developing a totally different type, rather than in greatly improving the present form.

A number of years ago the dynamo was already the most efficient transformer of power in use, being far superior in efficiency of conversion to the much older steam engine, boiler, turbine, or any of its class. It has long been so near to 100 per cent that improvements to increase this efficiency are necessarily of only small importance. The chief directions for improvements have therefore been to diminish their weight, cost, and attendance (self-regulation, fixed brushes, etc.), and to prevent the detrimental sparking. In all these directions important improvements were shown at the exhibition. The dynamo in its present form is a well-studied, well-developed, and highly efficient machine.

High and low tension.—Series lighting, so very largely used in the United States, appears to be almost unknown in France, and, judging from the exhibits from others countries, in Belgium and Switzerland also. The present system of running Jablochkoff lamps is the only exception of importance. High-tension, constant-current machines were therefore conspicuous by their almost total absence in the French, Belgian, and Swiss sections. There were several high-tension machines in the United States section, one in the English (Crompton), and one in the German (Steinlen).

With the exception of a few moderately high-tension series-wound machines for the transmission of power, the dynamos on the continent are mainly shunt or compound wound, for constant potential circuits of 60 or 110 volts, arc lights being usually run in derivation with incandescent.

Direction of development.—The tendency in France, as well as in other countries on the continent, seems to be to prefer to drive the larger dynamos directly from the engine by coupling the shafts, the belt being, to a great extent, confined to smaller machines. This naturally leads to slow-speed dynamos, and, consequently, to armatures of large diameter, which in turn, together with other considerations, leads to making the field multipolar. Many of the larger machines were therefore multipolar and with large armatures. In one prominent case (Siemens dynamo) the usual disposition of parts was completely reversed; the Gramme armature formed the outside of the dynamo, the multiple field magnets being inclosed by the armature. This type is used in a number of the large central stations in Berlin.

Alternating-current dynamos.—Alternating-current dynamos were exhibited only by two or three exhibitors, the most important of which were those of the Thomson-Houston Company and that of Ferranti.

Field magnets.—With the exception of the tendency to make the field multipolar for large machines, there were but few important modifications shown.

The most radical change was in the Rechniewski machine, in which the whole-field magnets are laminated like the armature, resulting in diminishing the weight and gaining other advantages.

Another feature of interest in several machines used chiefly as motors was a small pair of auxiliary poles just beyond the main pole pieces, to fix sharply the position of the neutral line, in order to enable the brushes to remain fixed in position for all loads. It appears to give very satisfactory results.

In the multipolar frames, a form much used is one having radial magnets with a yoke piece encircling them all in common, as in the Oerlikon machine described below. It necessarily makes a rather large and heavy frame and has the disadvantage that, as the coils are generally slipped on from the inside, there are no pole-piece extensions, and there is necessarily a comparatively large amount of dead wire on the armature.

The so-called "type supérieur" is also very common for bipolar frames. It is a simple U-shaped magnet like the Edison but with the armature at the top instead of at the bottom, whence its name, which has no significance in the sense of the word "superiority" in English. This form has the disadvantage that there is a very considerable downward pull on the armature due to the combined action of the magnetic pull and the weight of the armature, two forces which act *against* each other in the Edison form.

In the proportions of the magnets the tendency is to make them short and thick. Ironclad magnet frames do not appear to be coming into use to any great extent.

Armatures.—In armatures there were a number of features of interest.

The only radical change was in the Desrosiers dynamo, which is of the disk type, without iron. It has some interesting features, but it is doubtful whether it will prove an important departure from the regular forms.

The large diameters of multipolar armatures, necessitated by slow speed of revolution, have given rise to an interesting development, though not novel, of an adaptation of the drum winding to cores of great diameter, without loss of dead wire at the ends. The core resembles that of a large Gramme ring, but has the windings only on the outside surface. A further description will be found below in the detailed description of the Thury dynamo.

In general, for large machines, makers have diminished the number of layers to a single one, for machines up to the usual 110 volts, and in some cases even higher volts, as in the 600-volt Oerlikon machine. This feature of a single layer has developed the so-called "built-up" armature, of which there were a number exhibited. In these the armature wires or bars are made separately and are then placed in position, one next to the other, and afterwards connected together, in distinction to being wound on in form of a wire. This, as a rule, makes a perfectly regular, symmetrical winding of very neat appearance, and having other advantages. The use of teeth or lugs on the armature, between the wires, seems to be meeting with more favor. As it gives rise to injurious Foucault currents in the pole pieces, it necessitates some modifications. This is accomplished in the Rechniewski dynamo by laminating the field, and in a number of other forms by magnetically shunting, as it were, the iron of the core, by having a small amount of iron on the *outside* of the wires, as, for instance, by making the teeth meet on the outside, or covering the whole armature with a thin shield of iron. If the small loss of magnetism caused thereby accomplishes the object sought, as it appears to, it is a well-applied loss.

Brushes.—Brushes made of a fine copper gauze appear to be coming into use rapidly. Carbon brushes are also being used more frequently. Some improvements in brush holders also were shown, chiefly to prevent their heating.

Bearings and oiling.—Bearings are as a rule made large in diameter as well as in length. In the larger machines they are often supported on spherical pivots. The oil-cup feed is being replaced very rapidly by the ring feeder; so much so that the former method now forms the exception. In these ring feeders there is a reservoir of oil cast in the bearing below the shaft, and a very loosely fitting revolving ring rolling over the shaft carries the oil from the reservoir to the top surface of the shaft.

Exhibits by countries.—The exhibits of dynamos were pretty well divided among all of the principal countries who exhibited largely in the class of electricity. In numbers only, France excelled; but in importance and interest other countries were fully equal, especially Switzerland and United States.

Kilowatt.—In the accompanying detailed description of dynamos the term "kilowatt" will be used exclusively in referring to the output or power of a dynamo or motor. This term was adopted by the Electrical Congress of 1889 with a suggestion that it be adopted also by mechanical engineers to replace the arbitrary unit "horse power." It is a true unit of power, and is equal to 1,000 watts, as its name indicates; also to 1.3592 metric horse powers (or about four-thirds within 2 per cent), or 1.3406 English horse powers (or very nearly four-thirds within one-half per cent; 1 metric horse power equals 0.73575 kilowatts (or nearly three-fourths; 1 English horse power equals 0.74594 kilowatts (or very nearly three-fourths).

Comparative data.—It was intended to give here a number of the practical deductions of various important constants used in calculating and designing dynamos, but this had to be abandoned, as it was too difficult to obtain the desired information and to make the required measurements, as the exhibition administration forbid taking notes or making sketches, and whenever the information could be obtained from exhibitors it was generally with the understanding that it should not be published. This is to be regretted, as many valuable figures and constants could thereby have been deduced and useful deductions made. The writer is therefore limited here to a few very general deductions made from such information as could be obtained from published or public statements of the makers. The deductions are therefore necessarily crude, but will serve in a general way for comparison as well as for their absolute values. The only useful deductions that could be made are the relative weights and the relative prices, both reduced to common units.

Watts per pound.—The first is reduced to the number of watts obtained per pound of dynamo complete, from which it be will be seen in the following table that this does not vary materially with the size, so that in general the statement can be made that the power of a dynamo increases in proportion to its weight. Most of the figures lie between 4 and 7 watts per pound; in a few of the heavier machines they are as low as 2.2 while in the very light Rechniewski machine it is as high as 11.5. With a very few exceptions the dynamos in the table are all low potential machines. In one high potential arc-light series machine (Crompton) the output is as high as 18.5 watts per pound, if the data are exact. These figures naturally depend greatly on the speed, which is therefore also given here. As the output in general would be proportional to the speed, a better and more independent figure of technical interest, showing the relative values of the different constructions, would be the watts per pound divided by the linear velocity of the moving wire of the armature, thereby eliminating the speed and giving due credit to the larger armatures; but this requires the size of the armature, which could not always be obtained.

Price per kilowatt.—The other deduction, the cost of the dynamo per unit of power, has been reduced to the cost price in dollars per kilowatt of power. This, naturally, varies with the size of the machine; but it will be noticed also that it varies very greatly with the manufacturers, and that in general it is, for the same size, about twice as great for the American machines as for the European; as the former may be taken as fair prices here, it shows the very great cost of dynamos in the United States as compared with those abroad. Even with a high duty it would be more economical to import dynamos from Europe. In cheapening the cost of dynamos we have therefore much to learn from abroad. The prices are all *list* prices, most of which are subject to a discount, especially those from the United States.

INCANDESCENT LIGHT AND POWER DYNAMOS.

Name.	Kilowatts (1,000 watts).	Volts.	Ampères.	Number of revolutions.	Watts per pound.	Price in dollars per kilowatt.
UNITED STATES.						
Edison	0.25	110	2.25	2,400	2.8	550
Do	0.5	100	5	2,400	4.2	320
Do	1.0	110	9	2,100	3.7	195
Do	2.5	125	20	1,900	4.5	120
Do	5.0	125	40	1,800	6.0	95
Do	7.5	125	60	1,700	6.9	87
Do	10.0	125	80	1,600	6.8	83
Do	15.0	125	120	1,500	7.0	78
Do	20.0	125	160	1,400	6.9	76
Do	25.0	125	200	1,300	7.0	75
Do	30.0	125	240	1,200	6.9	74
Do	40.0	125	320	1,000	5.9	71
Do	50.0	125	400	700	5.1	72
Do	80.2	140	575	650	4.9	69
Do	150.0	140	1,075	450	4.8	69
Thomson-Houston (motor type)	1.5	....	....	2,500	5.0	234
Do	5.0	....	....	1,800	7.1	120
Do	10.0	....	....	1,600	7.3	120
Do	30.0	....	....	1,170	6.0	90
Do	50.0	....	....	1,020	7.1	76
Do	62.0	500	....	900	6.2	81
FRANCE.						
Edison Company (French), "type superieur"	2.2	....	....	2,000	5.5	53
Do	6.6	....	....	1,400	4.5	38
Edison Company (French), Manchester type	17.6	....	....	1,000	4.7	33
Do	39.6	....	....	650	4.3	24
Rechniewski	14.3	110	130	1,200	11.5	....
Breguet (Old Gramme type)	1.1	110	9	1,500	4.1	97
Do	38.5	110	350	600	7.0	31
Desrozier	14.0	100	140	350	....	76
Do	16.5	110	150	800	....	42
Do	17.9	105	170	350	6.7	....
Do	192.0	120	1,600	300	....	23
Belfort	2.0	....	....	1,300	....	115
Do	11.0	....	....	1,000	....	57
Do	43.0	....	....	550	....	44
Gérard	0.28	35	8	....	....	138
Do	2.2	110	20	....	....	44
Do	3.3	110	30	....	....	41
Do	5.5	110	50	....	....	35
SWITZERLAND.						
Oerlikon, lighting	1.95	65	30	1,600	2.5	89
Do	13.0	65	200	600	3.3	44
Do	65.0	65	1,000	300	3.5	33
Oerlikon, power	3.7	....	....	1,250	2.2	78
Do	36.8	....	....	600	2.8	32
Do	221.0	....	....	240	3.3	28
Thury	27.5	....	....	450	6.2	....
Do	55.0	....	....	250	5.5	....

INCANDESCENT LIGHT AND POWER DYNAMOS—Continued.

Name.	Kilowatts (1,000 watts).	Volts.	Ampères.	Number of revolutions.	Watts per pound.	Price in dollars per kilowatt.
SWITZERLAND—continued.						
Thury	125.0			185	9.5	
Zurich, lighting	18.2	110	120	800	3.9	
Zurich, power	25.8			750	4.3	
Winterthur	22.0	110	200	900	7.1	
BELGIUM.						
Dulait	11.0	110	100	700	8.3	
Do	35.8	110	325	650	7.3	
Jaspar	10.5	70	150	875		42
Do	20.0	100	200	600		37
ENGLAND.						
Westminster	32.0	80	400	420	8.0	
AUSTRIA.						
Ganz	1.7	110	15	1,400	3.1	
Do	11.0	110	100	600	4.3	
Do	44.0	110	400	375	4.5	

ARC LIGHT DYNAMOS (FOR SERIES DISTRIBUTION).

Thomson-Houston (United States)	1.8			1,250	2.5	306
Do	8.4			900	2.4	262
Do	15.6			820	3.0	212
Do	22.8			820	3.8	175
Breguet (Old Gramme) (France)	14.3	1,100	13	800	4.3	51
Crompton (England)	32.5	1,300	25		18.5	24

ALTERNATING CURRENT DYNAMOS (EXCITER NOT INCLUDED).

Thomson-Houston (United States)	35.0			1,500	9.8	69
Do	70.0			1,070	8.5	67
Do	140.0			680		64
Zipernowsky (Austria)	10.0	1,000	10		6.5	
Do	50.0	2,000	25		6.7	
Do	160.0	5,000	32		6.6	
Do	380.0	5,000	76		7.5	

Jury tests.—The electrical jury of awards tested quite a number of the dynamos for efficiency and indirectly also for some other features, but the results obtained were for their use as jurors and not for publication. The efficiency tests were made by the usual electrical method of measuring the losses in the field, in the armature, and in stray power (friction, Foucault currents, etc.). The dynamo was run as a motor at its true speed, with separately excited field, and the electrical powers measured. This test, which is decidedly simpler and probably more accurate than a dynamometer test, serves also to check some of the data furnished by the makers. The results obtained were probably within one-tenth to one-twentieth of their true value.

DETAILED DESCRIPTIONS.

As the number of different forms of dynamos exhibited is greater than the number of their exhibitors, no attempt has been made here to give a description of them all; nor was it thought necessary to give a complete description of any, as most of them have been described and illustrated in the technical journals.

The following descriptions are therefore limited to a short general summary of some of the more interesting though not always novel features. No attempt has been made at any classification, except into continuous and alternating current dynamos.

Awards.—The awards mentioned were not always for the dynamo alone, and are therefore omitted in some cases. In a number of cases the makers were represented on the jury and the exhibits were therefore not entitled to awards.

CONTINUOUS-CURRENT DYNAMOS.

Oerlikon.—One of the best exhibits of large and massive dynamos was that of the Oerlikon Co. (Swiss section, Grand Prize), the dynamos being designed by Mr. C. E. L. Brown. They were the only exhibitors who received the highest award, grand prize, chiefly for their dynamos. The only other two exhibitors of dynamos who received this high award were Thomson, and Edison, in the United States section, who, however, received it largely for their electrical work and researches in general.

There were three distinct types of dynamos in the Oerlikon exhibit: The first, a very large, massive, four-pole machine, for transmission of power; the second, for incandescent lighting; the third, a small, compact machine, chiefly for ship lighting. All three were coupled directly to their own engine.

Large Oerlikon.—The large one is shown in the adjoining illustration (Fig. 1) and is a good example of a large, massive, rigid machine of simple construction. It was one of the two largest dynamos at the Exhibition, the other being the large Edison dynamo of the same output, 150 kilowatts. It is a series-wound machine for the transmission of power, the magnets being wound with bands of copper 1 millimeter (0.04 inch) thick and as wide as the coil is long, about 12 inches, insulated by means of bands of paper of the same width. It is for about 250 horse power, at 600 volts and about 250 ampères.

The armature is a very neatly wound Gramme ring, about 40 inches in diameter, having a speed of 500 revolutions. This gives a velocity of the moving wire of 86 feet per second, which is very high, being almost double the usual velocity.

The field is very intense, being 51,000 effective lines of force per square inch, which is almost double the usual intensity. This is calculated from the electromotive force generated, the velocity of the wire, and the number of turns of wire on the armature, and therefore includes only the actual effective lines of force. This great velocity and intense field give the exceedingly high induction of 6.3 volts per foot of active wire, which is almost four times that in the usual machines, and is therefore probably the best obtained in a commercial machine. The magnetic density in the armature core is about 78,500 lines per square inch, which is not very high. As the area of the pole pieces is the same as the cross section of the cores of the field magnets, the magnetic density in these cores, assuming no leakage, would be 51,000 lines per square inch.

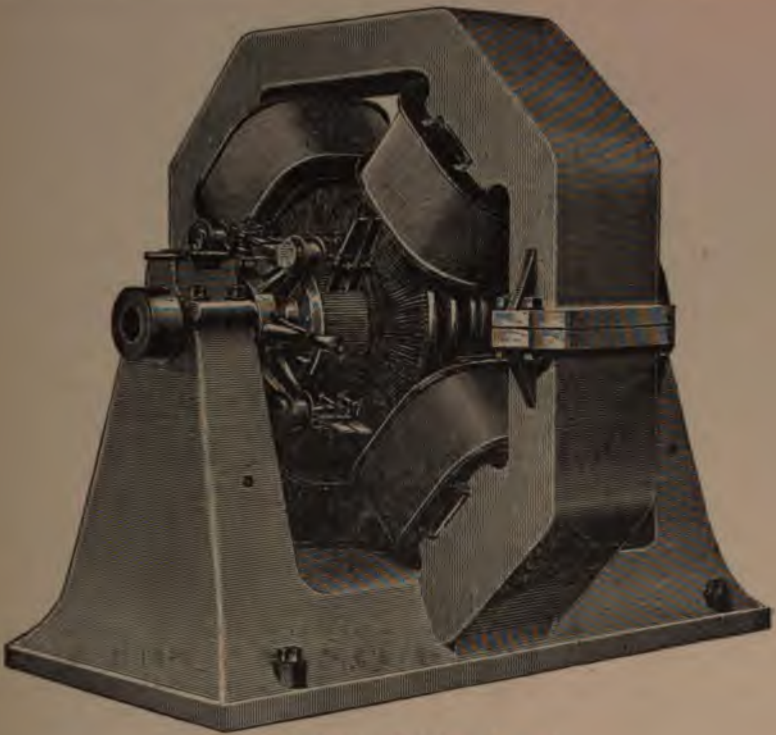

FIG. 1.—The Oerlikon Co.'s large dynamo.

From these figures it follows that there are 86 effective lines of force generated per ampere foot in the field magnet coils. The volts and amperes from which some of these deductions are made are probably a little too high, and, therefore also, the deductions which are based on the volts and ampères, but the difference is probably not very great.

The loss in the field is said to be 1,750 watts, from which it follows that there are about 20,300 effective lines of force generated per watt in the field, which is also very high, being considerably higher than usual. This high efficiency of the field is due partially to the very low relative resistance of the coils, their nearness to the iron, the great mass of iron, and the fact that the magnets are partially ironclad.

The weight of the machine complete is 38,000 pounds, and the output being 150 kilowatts, gives about 4 watts per pound of dynamo. The same figure for the Edison machine exhibited, having the same output, but less speed, 450 revolutions, is 4.8 watts per pound, showing that the Oerlikon machine is heavier even at a greater speed.

The selling price is stated to be 18,000 francs, or $348, making $23.2 per kilowatt. These machines are used for the transmission of power, the single motor being similar but slightly smaller.

Medium Oerlikon.—The second type of machine exhibited by the Oerlikon Co. is of interest owing to its armature. The armature wires, instead of passing over the outside surface of the armature core, pass through circular holes through the core lengthwise just beneath the surface; the core, therefore, extends almost to the pole pieces. The wires consist of straight copper rods inserted into these holes and soldered at their projecting ends to the bars which lead back through the inside of the ring. It is in effect an armature with teeth which close over the wire on the outside, the wire being thereby inclosed entirely in iron.

The speed—360 revolutions—is comparatively low, the conductor velocity being only 38 feet per second, and as the field is not very intense the induction is therefore only 1.75 volts per foot. The weight being 13,500 pounds, and the output 110 volts and 370 ampères, or 40.7 kilowatts, the relative output is only 3 watts per pound. It is therefore not a light machine, but that is due chiefly to its having such low speed. It is used chiefly for lighting in multiple arc.

Small Oerlikon.—The small machines, used chiefly for ship-lighting, coupled direct to a small engine, has a peculiar field, though its form is not new. It has only two field coils, but has four poles, and the field is nearly ironclad. The frame is a low, flat, rectangle, inclosing the coils and armature. The middle of the long sides act as two poles, and the ends of the cores through the horizontal coils act as the other two. It is very compact and rigid; in fact, could hardly be more so. The mass of iron in the field is comparatively great.

Rechniewski.—One of the most interesting improvements, and probably the most valuable of all those shown, was in the Rechniewski dynamo, exhibited in the Russian section by the inventor (gold damel) and in the French section by the Société l'Eclairage Electrique (gold medal).

The improvement consists simply in making the field as well as the armature of thin sheets of wrought iron, and having teeth on the armatures. The principle involved is that, for the same output, all parts of a dynamo may in general be made smaller and lighter if the field is made more intense. Now, the intensity of magnetism generated is dependent very much on the so-called "entrefer"—that is, the distance between the iron of the armature and that of the pole pieces, as this part of the magnetic circuit offers by far the greatest resistance. This magnetic resistance of the entrefer is very materially lessened by having teeth or lugs on the armature, extending out between the wires to nearly meet the pole pieces, a fact which was appreciated even in the early Pacinotti machines. But such teeth on the armature produce a very great and rapid periodic variation in the magnetism and thereby develop great and injurious Foucault currents in the pole pieces, so much so that they have in most machines been abandoned.

Numerous devices have been suggested and introduced to avoid this with more or less effect; Weston, for instance, cast his pole pieces with a few slots in them with the intention to diminish the Foucault currents; he also made the extremities of the pole pieces inclined, so as to avoid too sudden changes of the magnetism; Brown (see Oerlikon machine), made the teeth meet outside of the wire; Picou (see French Edison machine), made them so that they almost meet; Dobrowolsky connects the two pole pieces by thin iron bands, thereby losing some magnetism but apparently overcoming the effect of their heating; other makers do practically the same thing by covering the outside of the armature with iron wire, making a magnetic shield, as it were. The latter devices appear to be effectual; they are similar in effect to avoiding a spark in opening an electric circuit, by having a relatively high resistance as a shunt to the spark, thus avoiding to a great extent the injurious effects of the spark at a cost of some current.

Rechniewski, however, is more radical, and practically avoids the Foucault currents entirely by making the entire field of very thin sheets of iron, just as in armatures. He thereby has additional advantages: the iron used is of the very best and softest quality and therefore is better magnetically; the shape of the pieces is such that both armature and field disks are punched out of the same piece so as to have very little loss; furthermore, the whole field disk is in one piece so as to have no magnetic joints; as all parts are punched there is no further boring or shaping of the field; all that remains to be done is to bolt the plates all together, through punched holes, and to secure them to a base plate. The operation of punching is said to be quite cheap after the dies are once made, so much so that the whole cost of manufacture, for the same output of dynamo, is said to be considerably cheaper than that of the usual forms with solid wrought or cast iron fields.

There is no doubt that the machines exhibited are very small and light for their output, which shows that the iron and copper are more advantageously used. Any feature of a dynamo which enables a less quantity or cost of materials to be used in one part is a gain in a greater proportion than that of the weight saved. For instance, increasing the magnetic permeability of the iron of a core saves not only in the cross-section of iron but also in the copper of the coil, and thereby in the length of the core, etc.

The smaller Rechniewski machines are made in the ordinary horseshoe type of frame, like the Edison, but with the armature at the top; the large ones are made multipolar.

There being practically no Foucault currents, and the dimensions of both copper and iron parts being small, the dynamos can be built with a very high efficiency. A formula suggested by Professor Potier (see his paper read before the Electrical Congress, 1889), to determine the relative values or the relative economy of the frames of dynamos considered by themselves as a magnet, shows that the frame of this dynamo is far superior, magnetically, to any of those exhibited for which the figures could be obtained, the figures obtained (the lower ones being the better) being 7.4 as compared with values varying from 12 to 33 for other well-known machines. But this figure is of interest chiefly from a theoretical point of view, as it happens that the worst figure is that obtained from a machine which was apparently among the lightest and cheapest of those exhibited, giving over 18 watts per pound, and selling for about $24 per kilowatt of output.

The following data of one of the Rechniewski machines may be of interest: 110 volts; 130 ampères; 14.3 kilowatts; weight, 1,240 pounds; speed, 960 revolutions; linear velocity 31.5 feet per second; thickness of iron plates, 0.024 inch; 122 watts per pound of copper; 11.5 watts per pound of dynamo; electrical efficiency, 95 per cent; commercial, 92 per cent; total lines of force, 3,700,000; in armature core 135,000, in magnets 97,000, and in field 40,000, lines per square inch. It will be noticed from these that the dynamo is very light, giving double and even triple the number of watts per pound; also that the intensity of the magnetism is relatively very high.

A test made by the writer to measure the amount of magnetic leakage showed that, of the magnetism generated, only about 14 per cent did not go through the armature, the usual loss, in other machines, being about double this.

It was suggested that this machine could be used as an alternating-current motor just as it is, but it appears that it was not satisfactory, for some reason.

For a further description of the Rechniewski dynamo, with illustrations, see La Lumiere Electrique, February 16, 1889. See also

Bulletin de la Société Internationale des Electriciens, June, 1890, No. 69.

Desroziers.—The Desroziers dynamo exhibited by Breguet (French section, gold medal) attracted considerable attention, owing to its being totally different from the usual types.

It belongs to the class of disk machines, having no iron in the armature. In principle it resembles the Pacinotti disk dynamo of 1875, and also the disk dynamo devised by Edison a number of years ago and exhibited in the Electrical Exhibition of 1884 in Philadelphia as a historical model. It is therefore not new in principle, but has some novel features in its details.

The construction of the armature is necessarily very complicated, and it is a question whether it will compete very favorably with the much simpler, ordinary, well-built dynamos, as the few advantages gained seem hardly worth the extra complication; the cost of winding the armature must necessarily be quite great. In general appearance it resembles somewhat the old form of Siemens or the Ferranti-Thompson alternating-current machines, in which the armature is in the form of a thin, vertical disk revolving between the poles of horizontal magnets parallel to the shaft and arranged in a circle near the circumference of the disk. In the Desroziers machine there are six such magnets, each having wide pole pieces.

The armature is in principle somewhat like that in the well-known Ferranti-Thompson alternating-current machine, in so far that each wire passes out radially in the field between two opposite poles and returns radially through the next field of opposite polarity, thence out between the next, and so on; the currents induced in a wire are therefore in the same direction. Or it may be described as follows: Supposing the dynamo to have two sets of field magnets instead of six, the armature would, as far as the winding is concerned, be equivalent to a drum armature winding in which the cylindrical surface was developed into a flat disk perpendicular to the axis, the active straight portions of the wire being then radial instead of parallel to the axis. In one respect it differs, however, from multipolar machines; generally in such machines the sets of wires moving in a pair of fields are in multiple arc with all the other sets, but in this winding the coils in the different pairs of fields are in series, which has the advantage that should the fields be slightly different they will not induce different electromotive forces in coils which discharge their current in multiple arc.

Another device of interest, which is too complicated to be described here, is the method of so bending the wires outside of the field that they do not cross each other at right angles, but remain approximately parallel to each other in the same sense that the strands of a slightly twisted cable are approximately parallel, though they change their relative positions. This arrangement, however, brings a very large mass of dead wire at the outside and the inside ends of the active wires.

A detailed description, with numerous illustrations, will be found in l'Electricien for 1888.

Thury.—The Thury dynamos exhibited by Cuénod, Sautter et Cie (Swiss section, gold medal), have a peculiar frame and armature differing from the usual types. The armature is of relatively large diameter; the six flat field magnets surround this armature in the form of a hexagonal frame, each side of which hexagon is one of the magnets and is almost tangential to the armature; in each of the six corners the magnets are joined to pole pieces. It is therefore a very compact form for such a large armature, but the composite construction of the frame does not commend itself, and it adds greatly to the labor in constructing them. They are, however, very well built, and belong to the better class of the large machines exhibited.

The armature is of a peculiar type, which appears to be meeting with favor and which has undoubted advantages, as it enables the ordinary drum windings to be used on armatures of large diameter without increasing the dead wire on the ends; it thereby enables great linear speed to be obtained and permits making the field multipolar. The general principle is that each armature coil is in the form of a rectangle, laid on the cylindrical surface of the core, nearly tangential instead of diametrical, as in the usual drum armature; the distance between the long sides being equal to the distance between the center of the pole pieces, and each coil being two coil spaces in advance of the preceding one, as usual. It is, in effect, an ordinary drum winding, if the two north pole pieces, for instance, on the two sides of a south pole piece are considered as the equivalent of the one diametrically opposite in the usual form. The core of such an armature is a ring like that for a Gramme armature, but it has no windings on the inside surface, and the windings all cross each other on the two ends.

Edison.—The Edison dynamos are too well known to require description here. The one large machine exhibited was of the largest size made and is their unit for central station lighting. It is a 2,500-lamp machine, for about 150 kilowatts; speed, 450 revolutions. In their present standard type the old form of multiple magnets have been replaced entirely by a single pair; their length has been reduced and the diameter increased; the length of the armatures has been reduced and the diameter increased. All the fifteen different sizes of this type of their machines appear to have the same relative dimensions. The outputs are said to be very nearly as the third power of the dimensions. These machines probably rank among the best of the large machines at the exhibition, and are good examples of a rigid, massive dynamo of simple construction.

Edison claims to have been, and doubtless was, the first to appreciate the importance of very large and powerful magnets in dynamos, a feature which has since been universally adopted. He has built machines weighing 27 tons, the armature alone weighing 6 tons, but these were soon abandoned. The one exhibited is the largest size made now, and gives 140 volts 1,075 ampères, weighing 31,000 pounds net; this is equal to 150 kilowatts, making 4.8 watts per pound, the speed being 450 revolutions; it is therefore a relatively heavy machine. The selling price is at the rate of $69 per kilowatt, which is exceeding high, being about double that of other European dynamos.

There was exhibited also a small high potential machine of 1,200 volts, of the same general appearance, but with a field magnet winding in sections. No satisfactory explanation of it could be obtained. It is for the municipal system of incandescent lamps in series.

French Edison Company's dynamos.—The French Edison Company build a number of different types, depending upon the purpose for which they are to be used. The ordinary type for lighting is in general like that of the American Edison Company. They still sometimes construct them with multiple parallel magnets, and sometimes with two sets of magnets and the armature in the middle, in which forms the magnets are consequently very short. The cores are generally wrought iron with cast-iron pole pieces. They make dynamos also of the Manchester type, but prefer the other. The leakage of lines of force in this Manchester type was found to be 33 per cent, as compared with 20 to 25 per cent in the ordinary Edison form. The Manchester type of frame is probably one of the poorest forms for economy of the magnetism generated.

French Edison Company's motors.—For motors from 2 to 8 horse power, to be used in constant potential circuits, they make a new and interesting form devised by Mr. R. V. Picou. The frame is a circular yoke-piece having four radial magnets on the inside, terminating at the armature. Two of these are large and two small; the two large ones are diametrically opposite to each other, are of opposite polarity, and are shunt wound; the two small ones are series wound, and are each of the same polarity as the large one *preceding* them in the direction of rotation of the motor. The object is to keep the neutral line in the same position for all different loads, in order that the brushes may remain fixed in position for all loads—a very important feature for motors whose loads vary continually, especially when they are in inaccessible places. This regulation of the neutral line is accomplished by these small series magnets by their drawing the neutral line forward as much as the increased current in the armature draws it backward, thereby keeping it in the same place.

The large magnets are wound as the short shunt—that is, as a shunt to the armature, and not to the whole machine, the object of which is that for increased load—that is, current—the potential at the shunt magnets falls, whereby the field becomes weaker and consequently the speed of the motor tends to become greater, which balances any tendency of the speed to fall with increased load.

The price of these motors is about at the rate of $22.50 per kilowatt, which is very cheap.

French Edison Company's small motors.—For very small motors they make a Gramme ring armature of peculiar form, in which the outside wires of the armature are almost entirely encircled by iron, the outside surface of the armature being entirely iron. The coils are wound into cylindrical longitudinal holes through the armature rings near their outside surface. The wire is wound into these holes by being passed through a narrow slot cut through from the outside to these holes, these slots being just wide enough to allow one wire to be passed through.

The whole is in effect equivalent to having teeth or lugs on the armature, which are so much wider at their outer end than at their roots that they almost meet. The advantage is that the space between the iron of the armature and that of the magnets is exceedingly small.

They claim to obtain more watts per pound by this arrangement. An 8-ampère motor at 110 volts weighs 75 kilograms, which makes 5.3 watts per pound of motor. They are said to require much more compounding than other forms.

Crompton series dynamos.—The dynamos of Crompton & Co. (British section, gold medal) were the only ones exhibited in the British section. Their arc-light machines are probably among the best known in Great Britain, and are too well known to require description here. They were among the very few series-wound dynamos exhibited for high-tension constant currents.

The chief claim is for lightness and for maintaining a practically constant current, which is not materially affected by slight changes of speed and load. This latter is accomplished by increasing considerably the cross-section of the iron of the armature as compared to that of the magnets, the proportion being 1.0 to 0.98, while that in the usual constant potential machines is said to be 1.0 to 1.4 and 1.8. The magnets, being series-wound, are therefore normally supersaturated, while the armature is not. A slight increase in current, due to diminution of external resistance or to slight augmentation of speed, will, therefore, not affect the magnets materially, but will increase the counter-magnetism of the armature, which will shift its neutral line in the direction of rotation and thereby diminish the electromotive force of the machine, thus effecting an approximate regulation of the constant current.

In the characteristic of such a series machine, giving the relation between the volts and the ampères, the point of normal current, 25 ampères, would be slightly beyond the point of maximum potential; that is, it would be just beyond the beginning of descent of such curve. The maker claims that in other machines of this nature, namely, the Brush and the Thomson-Houston, the armature is also saturated, which therefore diminishes the efficiency of the machines and increases their weight and cost. In one of his machines, giving 1,300 volts and 25 ampères, or 32.5 kilowatts, the loss in the armature is given as 850 watts and that in the magnets 870 watts, giving an electrical efficiency of 97 per cent, while the commercial efficiency is stated to be 94 per cent. The weight of the machine is 1,760 pounds, making, therefore, 18.5 watts per pound of machine.

The selling price is $770, making about $24 per kilowatt.

In its construction it differs from almost all other machines exhibited in that the magnets are wound with wire of square cross-section instead of round, as usual, whereby the volume and weight of the coils are diminished. He claims to have been the first who adopted a radial depth of one-fifth of the diameter for the cross-section of the Gramme ring, and which, he claims, was an important improvement which all other makers have since adopted.

An illustration of these machines, though not accompanied by a description, will be found in the Electrical Engineer (London), August 2, 1889.

Crompton compound dynamos.—The same maker also claims to have been the first to develop and adopt the compound winding for constant potential machines in 1882.

A novel device used in his heavy-current machines is that, instead of using solid bars of copper, there are four bars of square cross-section, which are twisted through a half-turn about at the middle, the object of which is to prevent the generation of Foucalt currents in the bar itself, which are apt to exist when the bars are very thick. In the large Edison machines a similar principle is adopted, probably for the same purpose.

Belfort.—The dynamo known as the Belfort dynamo, exhibited by the Société Alsacienne de Constructions Mecaniques (French section, gold medal), is like an Edison machine turned upside down, the armature being at the top. The strong magnetic downward pull on the armature, which is the great objection to this form, is claimed to be overcome by extending the iron cores to the extreme end of the pole pieces instead of tapering them off as usual, but it is probably only a partial remedy for this evil. The cores are of round wrought iron, while the yoke and pole pieces are cast and fitted to this round core, thus facilitating the winding and removal of this coil if necessary.

An accessory of interest is a brass spun cap secured to the pole pieces and covering the end of the armature to the commutator. This adds greatly to the appearance and protects that end of the armature from the metallic dust of the commutator.

Another feature is that the commutator is made of steel bars secured only at the armature end, the inside of the commutator being quite open and the insulation between the strips being air. It can be readily cleaned and probably lasts much longer than one made of copper as usual.

Siemens.—Another dynamo exhibited by the same company and called the Siemens dynamo is interesting on account of the very odd form, though it is very doubtful whether the few advantages gained justify the increase in the complication.

It consists of an enormous Gramme ring about 6 or 7 feet in diameter and supported at one end, leaving both the inside and outside free from obstructions; the radial magnets, of which there are a number, are on the inside only; the windings on the outside of the Gramme ring are made of bars of bare copper, which at the same time constitute the commutator, on which as many sets of brushes slide as there are magnet poles.

The outside appearance of the machine therefore resembles a huge copper fly-wheel on which the brushes slide. It is in fact merely a multipolar Gramme machine with the magnets on the inside instead of the outside, the windings on the outside of the ring itself constituting the commutator or collector.

The chief advantage is that great circumferential speed is thereby attained at slow speed of revolution. The great amount of copper required on the ring and the great speed at the brushes are attending disadvantages, as is also the complicated link, gear, and lever mechanism for holding the numerous sets of brushes and for enabling them to be moved together and lifted off simultaneously.

This is the type of machine made by Siemens in Berlin and is used largely in some of the central stations at present being erected in that city. In the latter the dynamos are so large that they must be built, to a great extent, in place in the stations themselves. The armature in these acts as the fly wheel of the engine, to which it is coupled directly.

Thomson-Houston arc dynamo.—The Thomson-Houston (United States section) arc-light machine is apparently the same as it has been for a number of years. It appears to be commercially a very good arc-light machine, in spite of the apparently irrational construction of the field.

Thomson-Houston power dynamo.—Their dynamo for power and motor work is of the same type as the Edison, only that it has the armature at the top instead of at the bottom. One of these was placed side by side with one of the older forms of the same output, showing the great improvement in favor of the newer form in size, construction, and appearance.

Thomson-Houston miniature dynamo.—In the personal exhibit of Prof. Thomson was a miniature dynamo of some interest, as it is probably the smallest ever built. The object was to study the self-exciting property for a small shunt machine. Its armature was about 1 inch in diameter and 1 inch long, making 8,000 revolutions and giving 2½ volts and 3 ampères; its weight was 2.2 pounds, which corresponds to 3.4 watts per pound; the two largest machines at the exhibition, the Oerlikon and the Edison, each for 150 kilowatts, gave 4 and 4.8 watts per pound, respectively; the output of this little dynamo is therefore nearly the same as that of large ones. Small as it was it excites itself as a shunt machine, which is said to be quite remarkable. It is said to have been built with as nearly as possible the same relative proportions as their largest machine for the transmission of power.

Miot.—The distinctive feature of the Miot dynamo exhibited by Mégy, Echeverria & Bazan (French section, silver medal), is that there is considerable space between the poles pieces, it being greater than that part of the armature covered by the pole pieces; the coils on the Gramme armature, which are thereby rendered inactive, are short circuited by two brushes connected together, taking the place of the usual single brush for each pole. It is claimed that thereby the sparking is reduced, because the current is not reversed in the separate coils as abruptly as usual, which is one of the chief causes of sparking.

This idea is not new, however. It was used here many years ago. It is a question whether the increased amount of wire and the increased size of the whole machine justify this advantage.

Another feature which appears to be meeting with favor is that, besides the usual field-magnet poles, there is a small series-wound magnet resembling an additional field magnet, its pole pieces being placed a short distance beyond those of the large magnets and having opposite polarity to these. The intention is that the neutral point on the armature should thereby be fixed very definitely in its position for all different loads, so that the brushes do not need to be moved when the load changes.

This machine was one of those used to operate one of the two traveling cranes used in Machinery Hall.

Deprez.—The Deprez dynamo exhibited by the Société Anonyme pour la Transmission de la Force par l'Électricité (French section), is characterized by its having two Gramme armatures on the same shaft, with the pulley in the middle, between the two magnets. The field magnets are composed of two horizontal magnets parallel to the shaft, each one terminating at each end in a pole piece; or it might be said that the second armature was put in that part of the field which is usually a yoke piece.

By this arrangement each line of force is cut four times by the armature wires, instead of twice, as usual. It is claimed that thereby a greater output is obtained; it is a question, however, whether the additional complication is worth this possible slight gain. There is another claim made that a higher potential may be more readily obtained by two armatures in series than by one, on account of the current breaking through. This would be the case in cylinder armatures, but not in Gramme, as the danger in these is not between the wires, but between the wires and the frame. Unless the two frames of the armatures were insulated from each other this claim is hardly substantiated. It has the great disadvantage of a very long shaft and that the belt can not be removed without cutting it.

Gramme.—The chief features of the Gramme dynamos exhibited by the Société Gramme and the Companie Électrique are their simplicity and rigidity. The frames are all of the "type superieur," by which is meant a simple horseshoe magnet like the Edison, but having the armature at the top instead of at the bottom. They are neatly made and exceedingly simple in construction.

One of the most interesting portions of the exhibit of the Société Gramme was the historical exhibit of the Gramme dynamos, showing the different forms which have been built, from some of the very earliest, and representing the development of the present form.

Sautter-Lemonnier.—The dynamos exhibited by Sautter-Lemonnier (French section) are chiefly of the Manchester type with Gramme ring, for use principally with their search-light projectors and lighthouse lights, for which they have a world-wide reputation.

They exhibited also a very small dynamo coupled directly to a turbine steam-engine of exceedingly high speed, for use chiefly on ships. The whole engine and dynamo are exceedingly small and run very smoothly; notwithstanding the comparatively great consumption of steam, they appear to be meeting with favor for special cases, for which they have undoubted advantages, as they are portable and require practically no foundation. The following figures of these may be of interest. There are eight sizes built; for No. 2, next to the smallest, some of the figures are as follows: 70 volts 30 ampères, or 2.1 kilowatts; 8,500 revolutions; linear speed, 138 feet per second; induction, 0.85 volts per foot of total length of wire, which may be equal to about 1.5 volts per foot of active wire; this is not particularly high, considering the exceedingly high linear velocity, which is about three times the usual velocity in small dynamos.

The total weight of engine and dynamo together is only 550 pounds, giving the exceedingly high figure of 3.8 watts per pound of engine and dynamo together, which is better than that obtained in some dynamos alone without engine. The electrical efficiency is given as 88 per cent and the commercial 60 per cent. It is stated to require 180 to 200 pounds of steam per electrical horse-power; for the larger sizes about half this consumption. Size No. 8 is made for 400 ampères and 80 volts, the linear velocity in which is almost 250 feet per second, or almost 3 miles a minute!

Breguet.—The firm of Breguet (French section) exhibited quite a number of different varieties of dynamos, designed for different purposes, chiefly for ship lighting. With the exception of the Desroziers machine, described above, their dynamos have apparently no features differing materially from the usual forms. They use the Gramme ring armature, with frames of various well-known types. One of their types is the old original Gramme form of frame, but it appears that this is used only for small outputs. One of their specialties seems to be small vertical high-speed engines of compact form, coupled directly with the dynamo, chiefly for ship lighting, and adopted by the French naval department.

Pieper.—In the Pieper dynamo (Belgian section, gold medal) the armature core is made of iron wire instead of plates, as in the older Gramme rings. It is rusted and then coated with shellac before it is wound. The form of core is like that of a Gramme ring, but the windings are only on the outside surface and are on the drum system, the machine having four radial poles.

The armature wire is made of bare copper bars of rectangular section, with air insulation, which acts also as a ventilator, as the core in this case can not be ventilated as in those made of disks. These bars are connected at their ends by copper strips bent somewhat like a bracket, thus: ⏟, the middle of which is connected to the commutator. These pieces are all the same size and shape, and cross one another in such a way as to make very short and quite regular and symmetrical "heads" to the armature. It greatly simplifies the winding and makes it almost impossible to make an error in the winding or connections. The objection is that these end pieces must all be soldered to the bars, which presents difficulties, as "crosses" are apt to occur at these points, which burn out the armature.

Zurich.—The Zurich machine exhibited by the Société des Téléphones de Zurich (Swiss section, silver medal), and shown in the adjoining illustration (Fig. 2), was, besides the Lahmeyer, the only dynamo constructed on the "ironclad" principle, which appears to have been invented, as applied to bipolar machines, a few years ago almost simultaneously by three different inventors, Wenstrom, Hering, and Lahmeyer, in Sweden, United States, and Germany, respectively.

In this form the relative position of the coil and its iron core are reversed, the iron surrounding the coil; this is really the most rational form for a magnet, as all the lines of force have a complete circuit of iron, instead of partly of air, which is almost the highest resisting body for lines of force.

There is no external magnetism in such machines, and they are for this reason especially applicable for places such as on ships or on tram cars, where such external magnetism is very objectionable—in the former on account of the compass and in the latter on account of the effect on the watches of passengers.

They are at best, however, heavy, but have the advantage of being very compact and solid.

Their external appearance, as will be seen from the illustration, is that of an iron box, nothing being visible except the ends of the bearings and the commutator. The armature is therefore well protected and at the same time readily accessible.

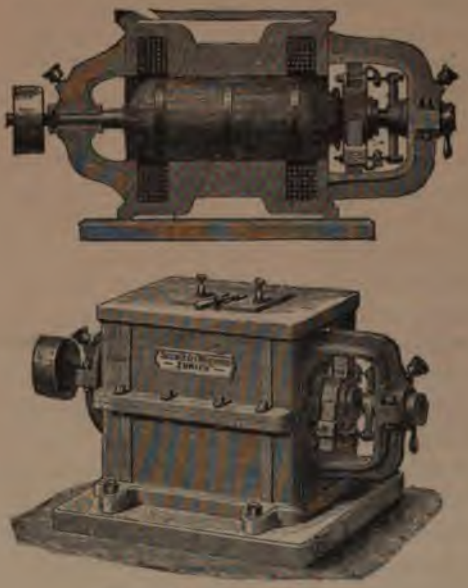

FIG. 2.—The Zurich dynamo.

Jaspar.—The Jaspar machine (Belgian section, gold medal) has changed very little from the original type. Its characteristic feature is a Gramme armature of great length as compared to its diameter, resembling in its proportions a drum armature. It is probably the only Gramme armature made with such proportions. There is only one layer on the armature, and the number of coils is comparatively great. The chief claim for it is cheapness. For greater outputs he uses an octagonal frame in one piece, having four radial magnets, whose ends form the pole pieces.

A characteristic feature is a set of three large, bare, copper rings, fixed to the frame near the brushes and concentric with the armature. These serve as universal connectors with which all connections between the four magnets, the eight pairs of brushes, and the machine terminals are made.

Dulait.—The Dulait dynamo, exhibited by the Société Anonyme Électricité et Hydraulique (Belgian section, gold medal), is in appearance almost identical with the Victoria-Brush or the Schuckert-Mordey machine. It has four poles and is compound wound. The advantage of this type of machines is the great diameter of the armature, and the consequent great inductor speed with relatively slow speed of revolution. It has the disadvantage of this type that it is very difficult to take out the armature should anything happen to it.

Henrion.—The Henrion dynamo (French section, gold medal), shown in the adjoining illustration (Fig. 3), is a slight modification of the well known Schuckert type. The four horizontal magnets, instead of being in a vertical plane, as in the Schuckert form, are in an inclined plane, so as to enable the armature with its shaft to be lifted out quite readily, the inability to do this being the chief fault of the Schuckert form. This dynamo was the only French one exhibited for high-tension constant current for arc lamps in series.

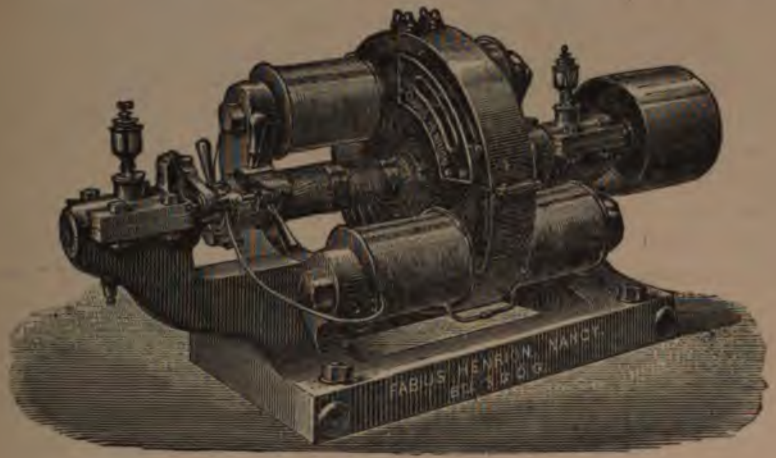
FABIUS HENRION, NANCY.
BTE S.G.D.G.

FIG. 3.—Henrion dynamo.

Sperry.—In the Sperry dynamo (United States section, silver medal) the Gramme armature is held at one of its ends, leaving the inside free for additional pole pieces. The pole pieces are split somewhat like a tuning fork, in the slot of which the armature moves, so that almost the whole length of the armature wire passes through the field, instead of only the outside portion as is usual. By this means it is claimed that the induction is increased. This may be so to some extent, as the resistance of the magnetic circuit is thereby diminished. A good illustration of the machine will be found in the Electrical World, June 15, 1889.

Perret.—In the Perret motor for very small powers (United States section, silver medal), the field magnets of the horseshoe type were made of links of punched wrought iron, jointed together by pins, so as to form two joints at the end of the yoke piece. The chief object of this appears to be that the whole magnet may be straightened out to form a straight bar, which can be put into the lathe to wind the coils on to it. It would seem, however, that this saves merely the work of winding the coils on spools, which are then slipped over the cores. The drum armatures, of only 2 inches in diameter, having 11 coils, and wound for 110 volts, are exceedingly neat examples of armature winding.

Postel-Vinay.—In the Postel-Vinay dynamo (French section) the magnets are made of cast steel in preference to cast iron, as it is claimed that the former has better magnetic qualities than the latter.

Gérard.—The Gérard machine (French section) is of some interest, owing to its great simplicity and cheapness. It has four radial magnets like many others, but the armature consists simply of four similar magnets, only smaller, and joined at the shaft forming a sort of double Siemens H armature; the alternating current produced is redressed at the four-part commutator. They are chiefly for small outputs.

Contades.—In the Gramme armature of the Contades dynamo (French section, honorable mention) the coils are wound separately on links which are afterwards secured by pins, forming the round Gramme ring; but its application was limited to quite small machines.

ALTERNATING-CURRENT DYNAMOS.

General.—The exhibits of alternating-current dynamos were very few, and of these there were only a very few of interest. Most of those exhibited were of the older well-known types. It is to be regretted that there were so few exhibits, as the subject is of much more importance than would appear from the few exhibits.

Thomson-Houston.—Among the most interesting features in this branch were some of the novel points in the Thomson-Houston (United States section) alternating-current machines. One of these is compound wound or "composite," as the makers term it, in order to maintain a constant potential. The connections are shown in the adjoining cut, Fig. 4. The machine has ten radial field magnets, which are wound with a coarse and a fine winding. The armature coils are wound flat on the cylindrical surface of the armature.

The fine-wire field coils, corresponding to the shunt coils of an ordinary compound-wound machine, are excited by a separate machine as shown; the coarse-wire coils are connected in the main circuit as series coils. This is accomplished by the following device: One end of the armature coils is connected directly to line by the sliding col-as shown; the other end leads to a commutator or redresser g numerous insulated bars, the alternate ones of which are cted together, whereby the alternating current is redressed, , as shown, around the magnets, and back to the other brush of ommutator, where it is again commuted into an alternating-

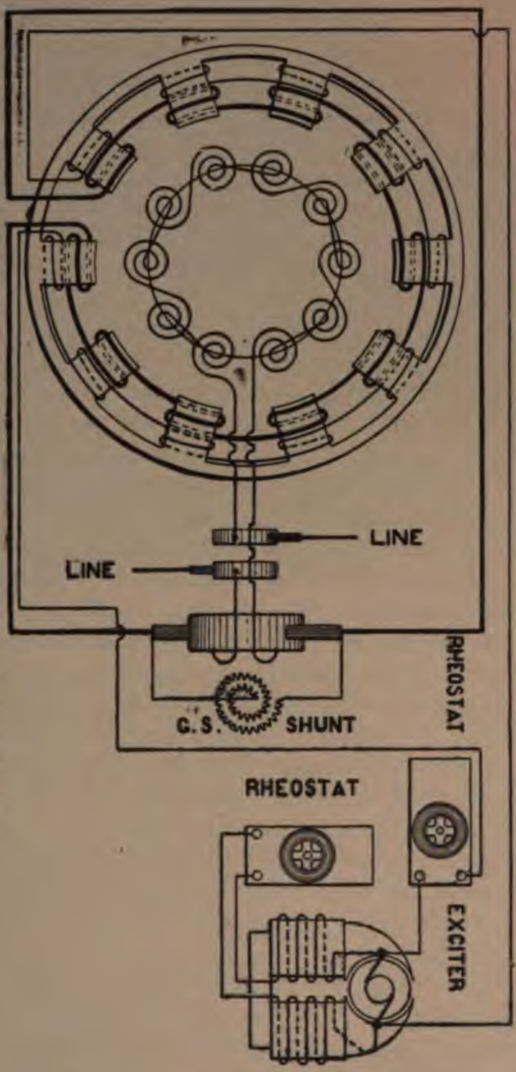

FIG. 4.—Diagram of the Thomson-Houston alternating-current dynamo.

nt, and thence it passes to the line through the other collecting by this means the current is redressed in that portion of its t only which passes around the field magnets.

hunt coil of German silver, having some self-induction, is con- l to the redressing brushes as shown; by adjusting this the proportion of the series excitation, and therefore the characteristic, may be varied for each particular installation. This coil also acts to diminish the sparking.

An interesting feature of this is that notwithstanding the great current which is redressed there is almost absolutely no sparking at the redressing commutator. This is partly due to the fact that the difference of potential at this redresser is very small. In another machine this same redresser is used to make the machine self-exciting. The current from a few separate and independent coils on the armature is thus redressed and is used to excite the field.

Thomson alternating-current motors.—In the personal exhibit of Prof. Elihu Thomson were shown some experimental motors of interest on account of their radical difference from all others in their action. They have been described in the journals in connection with his other recent researches, and are therefore probably well known to those particularly interested.

The principle is briefly as follows: When running normally the armature is short-circuited and has no connection with the circuit; the current in the armature coils is generated by the induction from the field coils as in a transformer, but owing to the retarding effect of this induction the repulsions between the armature and the field coils, or secondary and primary as they may be called in this case, are greater than the attractions, and there is therefore a continual repulsion between the two, which rotates the armature.

In order to arrive at the conditions for producing this induction at the right moment the motor must first be started. This is done by an auxiliary commutator and brushes, by means of which the motor is first connected as an ordinary continuous-current motor, even though the current is alternating. As soon as the proper speed is reached, which is determined by the unison of the two musical notes heard, or by an automatic governor, the armature is disconnected from the main circuit and is short-circuited.

This motor is only an experimental one; in the present form it could not be used in practice. One great and fatal objection is that if the speed is reduced even only slightly by overloading there will no longer be the required synchronism and the motor will stop completely.

Ferranti.—There was a Ferranti machine exhibited by the Société l'Éclairage Electrique, but it presents few points of novelty except in details. One of its features was that half of the machine could readily be slid off to one side to enable it to be cleaned and dusted around the internal parts. This cleaning had to be done once every day. The oiling was continuous by means of pipes from an elevated reservoir into which the drains were pumped continuously. The machine was for 175 horse power, giving 2,400 volts and making 500 revolutions. There were 20 poles, and the mean radius of the armature was about 43 inches.

Heissler.—The peculiarities of the Heissler alternating-current machine (United States section, gold medal) are that the field magnets rotate like in the Gramme alternating-current machine, and the coils in which current is induced are fixed and are connected in series in two groups whose coils alternate. By this alternation and division into two groups it is claimed that better induction is obtained than if they were all connected together as one. These two groups feed two different and independent circuits.

Maiche.—The small alternating-current magneto exhibited by Louis Maiche (French section) was interesting as an oddity, as it has neither brushes, collector, nor moving wire. It is not the only one having these features, as the Klemenko (Russian) dynamo exhibited as a commercial machine in Vienna Exhibition in 1883 was of a similar nature, though the construction was different.

The coil in which the current is induced is fixed to the field magnets; the revolving armature consists of a piece of iron having projections on its surface which come close to the field-magnet poles and into which the lines of force pass. These projections are so spaced that the lines are drawn alternately into one and then into the other, and in thus changing their position they cut the the coil, thereby inducing a current. The relative output is probably quite small.

The brushes for an alternating-current machine present so few objections that it does not seem advisable to get rid of them at the cost of greatly increasing the size of the machine.

DYNAMO ACCESSORIES.

Gauze brushes.—In a very large proportion of the dynamos exhibited the brushes used were made of wire gauze in place of the usual foil. They appear to be very satisfactory and are coming into use very largely. They are made of a very finely woven-wire netting or gauze of soft copper, somewhat like that used in paper-making. They consist of a number of layers of this gauze over one another and bound together by a wrapping or covering of the same material. They are soft and pliable, and do not "sing" or "scream" like the hard, elastic foil brushes. They can very readily be made for any current capacity by the attendant of a dynamo himself. None of them were noticed on any American dynamos.

Carbon brushes.—Another style of brush which is coming into use largely, but which was noticed only on the motors for cars in the United States section, is simply a slab of carbon, held so as to be almost or quite perpendicular to the surface of the comutator. The chief object of their application in this case was probably that the motor can turn in any direction, and that any wear will not change their position, as in the tangential brush. The objection to them appears to be that they are apt to "scream" or "cry," but it is claimed that if the commutator is quite smooth they will move quietly and will not wear the commutator unevenly, so as to cause "screaming." The idea is not new, but it does not appear to have come into use until quite recently.

Brush accessories.—In one of the dynamos the copper brushes were split at the holder end, so as to leave room for the clamping bolt. This device greatly simplifies the brush-holders. The well-known device of shunting the brush holder, by a flexible wire attached to the brush clamp and to the pin on which the holder turns, is being used by quite a number of makers. The object is to "take the heat out of the holder," or, in other words, to reduce the resistance, which sometimes becomes very high, at the sliding contact of the pin on which the holder turns, and which sometimes diverts the current so that it passes through the springs, thereby heating them and drawing their temper. Another old device, which is being adopted largely, is a fixed guide attached to the holder to mark the exact length to which the brushes should project from their holder. Another device for the same object, though not as good, is to mark two diametrically opposite points on the commutator, by which the brushes are adjusted before starting.

Brush-holders.—In the Alioth dynamo there was a very ingenious brush-holder of simple and rational construction. Besides its simplicity and cheapness, it has the advantage of avoiding entirely all sliding contact at the pivot, which contact is so often the cause of trouble. It consists of a straight flat spring, composed of a large number of thin sheets of spring copper, resembling the ordinary foil brushes. One end of this is securely clamped to the usual rod on the rocker; the other end is soldered to a clamp which holds the brush proper. There is therefore no loose or sliding contact in any part, while at the same time the brush is held with all necessary elasticity. The brush itself is almost perpendicular to this flat spring, the object being that when the pressure is being adjusted at the fixed end of the spring the end of the brush remains in the same position on the commutator. Similar brush-holders, differing only in detail, were noticed on the Belfort and on the Henrion dynamos.

Driving-gear.—Some of the Gramme machines exhibited were driven by friction pulleys of paper disks clamped together. There was one on each end of the shaft, and they rolled directly on the surface of two large cast-iron pulleys. The pulleys had a 9-inch face, and each transmitted about 8 horse power at a surface speed of 45 feet per second. They were only slightly warm after running. Breguet exhibited a Raffard coupling for connecting the shaft of the dynamo direct to that of the engine for direct driving. It is flexible and elastic, the transmission taking place through the medium of rubber bands.

Another coupling for direct driving was exhibited by Weibel, Briquet et Cie (Swiss section), the object of which was to double the speed of the shaft which was driven. This was accomplished by means of a pecular link and crank movement contained in the coupling, a description of which will be found in "Engineer," London, July 19, 1889, p. 48.

Dynamometer.—Some of the dynamos and motors of Deprez were arranged to measure and record the work which they were consuming. The field magnets are supported and balanced so as to be able to turn easily through a small angle around the shaft as a center, the turning force being the magnetic force at the surface of the armature. This deflection is made to move a small friction roller from the center toward the circumference of a revolving disk perpendicular to it. This disk is revolved by the dynamo shaft and drives the friction roller with a greater or less velocity, according as the latter has been moved a greater or less distance from the center; as that displacement is proportional to the deflection of the magnets, the number of revolutions of this roller recorded on a counter will be proportional to the product of the number of revolutions of the dynamo and the force at the periphery of the armature, and will therefore measure the work.

References.—For regulators and other accessories to systems, see "accessories."

TRANSFORMERS.

General.—The system of distributing electricity by means of high-tension alternating currents, and converting these into quantity currents by induction in transformers, was suggested and even patented a number of years ago, but it was not developed into a practical and successful commercial system until within the last few years, and it may therefore be classed among the more recent developments in the distribution of electricity. It was exhibited the first time at the Vienna Electrical Exhibition in 1883, by Gaulard & Gibbs, but although it attracted much attention there the system does not seem to have given very satisfactory results until a number of years later, when it was developed independently in Austria, the United States, and England, into a successful commercial system, and it may now be classed among the most important of the recent developments. The allied system of transforming continuous currents, though older, does not appear to have developed into an important system.

Exhibits.—There were so few exhibits of transformers that it may be said that in this branch the exhibition did not represent the present state of the art. The Thomson-Houston multiple arc distribution and the Jablochkoff candle series distribution were the only two commercial systems exhibited in operation. It is to be regretted that this should have been the case, as it would have added greatly to the interests of the exhibition to have had this new system more widely represented.

Mr. Louis Maiche, an exhibitor in the French section, claims that the principle of this system of transmitting electricity of high tension and converting it by means of transformers into low tension at the place of consumption, was patented by him as early as September 15, 1880, and that his patent was sustained by a decision in the United States patent office.

The Thomson compensating system, exhibited by the Thomson-Houston Company, although somewhat similar in its object and apparatus, is not properly a transformer system, and is therefore described under another heading. (See "Systems of transmission and distribution.")

As usual with newly developed systems, it was not possible to obtain from the exhibitors figures and data regarding transformers. The following detailed descriptions must therefore be limited to a mere mention of the exhibits.

Alternating current transformer.—The Thomson-Houston Company had a few transformers in daily use. They were made of a pile of sheet iron plates having retangular holes for the coil and an opening through which the coil was introduced; this opening was then closed by a tightly fitting wedge-shaped plug, also laminated. There were two styles of plates exhibited, one formed like the letter **H** and the other like the letter **E**. In the first the coil must be wound on to the pile of plates and can not be removed without unwinding. The plugs are introduced at the top and bottom. In the second form the coil is wound separately and then placed into the pile of plates from the side. This is the new form which seems to be preferred. The coil can readily be removed for inspection or repairing. In both forms the magnetic circuit is completely of iron, and each line of force traverses two joints in the iron. No data regarding the dimensions, weights, or capacities could be obtained. The same forms of plates were used for their self-induction or compensating coils in their compensating system, which see under that heading. (See "Systems").

Constant alternating current transformer.—In the personal exhibit of Prof. Thomson was shown an interesting transformer in which the secondary circuit would generate an alternating current of constant quantity—that is, of a fixed number of amperes—for variable resistances in the external circuit, the primary circuit being connected to the usual constant potential mains. Usually the secondary current has a constant potential instead of a constant current strength. The principle of this transformer is that a portion of the magnetic circuit is an air space, which acts as a great magnetic resistance. This gives the transformer a characteristic curve for volts and amperes in the secondary, which is practically a straight line between certain limits, between which the current will, therefore, not vary very much for different external resistances. It was shown in operation with a constant alternating current arc lamp of about 50 volts in the secondary, the primary being connected to a 1,000-volt multiple arc circuit.

Jablochkoff candle transformers.—In the system of distribution used at present for the Jablochkoff candles, there is a transformer with each lamp containing a number of candles. These transformers are all in series. The several candles in each lamp are all in multiple arc on the secondary circuit of a transformer, but their resistance when not lit is so very high that practically all the current passes through the one which is burning; when this is consumed it cuts itself out by melting a fuse; the potential in the secondary circuit then increases sufficiently to light one of the remaining ones, and so on until all are consumed.

Continuous current transformers.—The apparatus exhibited by the Popp Company (French section, silver medal), called an "onduleur" (undulator), is for enabling an ordinary transformer to be used on a continuous-current series circuit. It consists essentially of a commutator, which rapidly reverses the high-tension continuous current, making it an alternating current, which then passes through any convenient transformer, where it is converted into one of low tension.

The main feature is that the current is changed in direction very gradually; hence the name "undulator." The actual commutation takes place at the moment when the apparatus is short-circuited. This is accomplished by a rapidly revolving cylindrical commutator, which makes the following series of connections: The line current passes through the transformer and a resistance in multiple arc with it; this resistance is arranged in a succession of steps, in series, each connected by brushes to this commutator; the commutator, in revolving, brings one after the other of these resistances into circuit, and finally opens that branch, when the whole current goes through the transformer; it then puts them into circuit again and reduces their number, step by step, until this resistance, and therefore also the transformer, are short-circuited, at which moment the commutator reverses the current.

This series of connections is repeated in very rapid succession. It will be seen that the alternating current is thereby made to vary gradually and the sparking is very greatly reduced. There are always two such commutators, with their transformers, at one station, the two commutators being connected to the same revolving shaft, but in opposite phases. The object of this is that the two waves of the primary current balance each other, so as not to affect the rest of the main line or the dynamo. The commutator, which must necessarily revolve very rapidly, was turned by a small compressed-air motor, supplied from the compressed-air mains of this company, which are laid by them for general power distribution in parts of the city of Paris. The economy of this system of transformers can not be very great, and its application is necessarily limited.

The Gramme Company exhibited a continuous-current transformer in the form of a dynamo with a double winding on its armature, one part of which was for driving it as a motor from the high-tension current and the other was the generator for the low-tension current. It was said to be exhibited only as a historical model, the device being comparatively old and little used.

ARC LAMPS.

Historical.—In the Centennial Exhibition of 1876, held in Philadelphia, there were among the exhibits from France, in Machinery Hall, a few arc lamps run from dynamos. They were exhibited not as a curiosity, but as a commercial system of lighting. This was the first exhibit of the commercial arc lamp at a large international exhibition, and it was probably the first introduction into America of the arc light as a means of subdivided light. Although individual arc lights may have existed here before that time, yet they were more in the nature of experiments, and can not be said to have been commercial lamps.

The arc lamp had been introduced in France in the winter of 1874 and 1875 in permanent installations for lighting shops and factories. Prior to this the only use seems to have been for single large lights for light-houses and similar purposes, which use is said to date back fifteen years prior to that. This French exhibit at the Centennial at Philadelphia seems to have been a seed sown on good soil, as a year or two later several inventors, like Brush, Thomson, Houston, and others, began electric arc lighting on a commercial scale. This was followed by great developments and very rapid progress, until at the present time arc lighting forms one of the large industries of the United States. After the very rapid developments of the first few years, progress in the arc lamp itself had been slow, but not unimportant. The chief developments were in the systems of distribution rather than in the lamps themselves.

At the electrical exhibitions of Vienna in 1883 and in Philadelphia in 1884 arc lamps were already well developed, and but little improvement has been made since. It was from the beginning of its general introduction, and is still at this time, probably the most efficient means of converting energy into light, though not necessarily the cheapest. Notwithstanding that it is a great waste of the energy of oil and coal gas to burn it for lighting, yet these are still important competitors of the more economical arc light, in several features.

In general, the direction of development of the arc lamps as shown by the exhibition is different in the Continental countries from that in the United States. In these countries the usual method of distribution of arc lamps is in multiple arc on constant potential circuits, the series distribution being quite rare; in the United States, on the other hand, it is quite the reverse, the former system being a great exception. This has led to a different direction of development of the mechanism of arc lamps abroad, as also to a much wider range of brightness.

Series lamps.—In a series system, such as is used in the United States, the current is constant throughout the whole circuit; as the potential of all arc lamps is nearly the same, and can not be varied to advantage, it follows that all the lamps in a circuit are of about the same candle power; furthermore, as one and the same current flows through them all, it makes all the lamps more or less dependent on each one. A lamp which could open the circuit would be fatal to such a system. Such a circuit is not easily broken while running, without total destruction of the parts where the break occurs, and consequent great fire risk on account of the persistence of the arc which forms at the break.

These conditions led to constructions of lamps in which such things can not occur, including safety devices and automatic cut-outs to prevent accidents, devices which are scarcely to be found in foreign arc lamps. In a series system it is the potential which varies as the carbons burn away, and which is therefore used as a means of effecting the regulation. The shunt coil is therefore the important one; the series coil, being traversed by a constant current, may therefore be, and in many lamps is, replaced by a spring or weight.

Multiple arc lamps.—In the multiple arc distribution many of these conditions are reversed or different. In such a system it is the potential which is constant and it is the current which will vary as the carbons burn away. The series coil is therefore the most important one for effecting the regulation, while the shunt coil could theoretically be replaced by a spring or weight. The lamps are independent of one another; no persistent arc will form if the circuit is opened; therefore no safety devices and cut-outs are required. As the current for each lamp is not necessarily the same, it has led to the development of arc lamps of small as well as very great candle power on the same circuits, requiring as little as two to as many as fifty ampères, making a much more flexible system, which also has the advantage that arc lamps can be put on the ordinary incandescent system without the special independent dynamo required in the series system.

It appears, however, that in practice arc lamps can not be run directly in multiple arc; such a distribution is found to require a dead resistance to be placed in series with each lamp; this resistance represents not only an additional piece of apparatus but a constant and considerable waste of power, which in general is about 20 per cent of the total power used, and in many cases as high as 30 per cent. The system is therefore very faulty in this respect. This external dead resistance appears to be used not only to prevent the great rush of current should the carbons touch, as at starting, but it appears to be essential in some systems to effect a regulation, because in some lamps this regulation is effected by a shunt coil, which would be useless, because it would represent a constant force, were it not for this dead resistance. The regulation is in such lamps dependent on the variation of the loss of potential in this dead resistance caused by variations of the current in the arc, for if this dead resistance were zero there would be no change of potential at the poles of the lamp even if the current in the arc varied very greatly. This external resistance must therefore be considerable in order to enable the regulation to be effected by virtue of its resistance.

Feeding of the carbons.—Another feature which a multiple arc distribution seems to develop is that the feeding of the carbons must be a very gradual one and the regulation must be very sensitive, as a very slight change of the length of the arc makes a very appreciable change in the current, and therefore in the candle power. The foreign lamps are therefore essentially different from ours in that the regulation is a much more sensitive one, and consequently the light is very much steadier. Hissing and flickering, so common in our lamps, is the exception with these. The "drop" principle, which is the one almost universally used here, in which the carbon drops down suddenly during certain stages of the regulation, would be almost fatal to a multiple arc system. At the same time the foreign lamps are in many cases far simpler in their construction, even though the regulation is a much better one. This is to some extent due to the several safety devices which are necessitated by the series system and which are not necessary in the multiple arc.

In the usual system the arc lamps are either directly in multiple arc in constant potential systems of 70 volts, or two in series in systems of 110 volts. In the former the loss in the dead resistance is about 25 volts and in the latter about 20 volts.

One of the most frequently adopted principles of regulation of these lamps is that the carbon, in descending, by its own weight turns a multiplying system of gearing, the rapidly moving escapement of which is controlled by a brake which is operated by the magnet, usually series wound. The descent of the carbon may therefore be made very gradual and regular. Another principle frequently used is to force the carbon down, so as to make the action independent of any weights or friction. Make-and-break movements and small electric motors were also used in a number of lamps. The Jablochkoff candle still holds a prominent place, but apparently of diminishing importance. It still remains one of the leading of the very few alternating-current lamps.

New forms.—Although new departures from the usual arc lamps are attempted continually, there were none of importance exhibited except the new Pieper lamp, which, being really an incandescent lamp, is described under that heading.

Cored carbons.—Cored carbons are almost universally used for the upper or positive pole and plain ones for the lower. This also is one of the reasons why the lamps burn more steadily. They are only very little more expensive than the plain. (See "Carbons," under "General supplies.")

Small lights.—One of the interesting features of arc lighting exhibited was the more extended introduction of lamps of comparatively small candle power, requiring as little as three and even two ampères. They may be used to advantage to replace the large incandescent lamps.

Diffusion.—In a number of lamps both carbons are moved, the arc, therefore, remaining in the same position, which enables very small milk-white globes from 6 to 8 inches in diameter to be used for small lights. This diffuses the light in such a way that the effect is a much more satisfactory and agreeable one. A lamp of that kind may be placed over a table, or in even a small room, without being objectionable, and it does not hurt the eye to look directly at it. In another system the position of the carbons is reversed, so as to throw the light up against a reflector in order to diffuse it. It is claimed that when so diffused less light is required, because the pupil of the eye does not contract so much, nor are there such black shadows.

Exhibits by countries.—The exhibits of arc lamps were very numerous. Though mostly from France, there were many and very good ones from England, United States, Belgium, Switzerland, and one from Germany.

Cost.—The average cost of a good arc lamp abroad appears to be about $40.

DETAILED DESCRIPTION.

There were about as many lamps of totally different construction as there were exhibitors of lamps, an arc lamp being one of those pieces of apparatus of which it is very easy to invent a new and distinct mechanism. It would, therefore, be quite useless and uninteresting to give a detailed description here of more than one or two of the better ones, with a short summary of the more interesting points of some of the others. For complete descriptions the reader is referred to the journals and books in which most of them have been described.

Cance.—The Cance lamp exhibited by the Société Anonyme d'Appareillage et d'Éclairage Électrique (French section, gold medal), though not a new lamp, is of interest on account of its steadiness and its wide range of candle power. The general principle of the lamp mechanism is shown in the adjoining cut, Fig. 5.

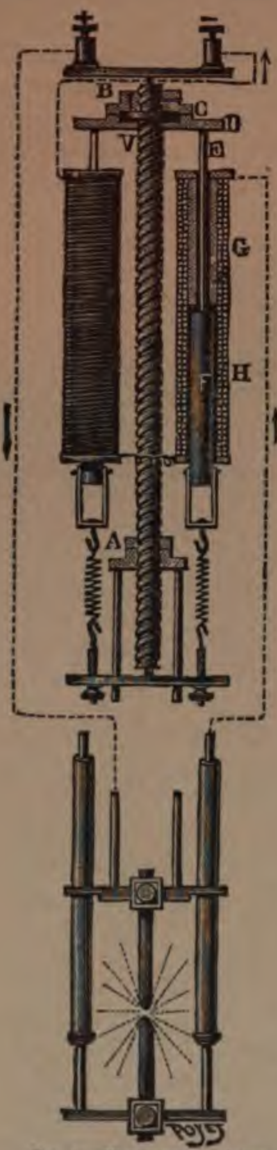

FIG. 5.—The Cance arc lamp.

It consists, in general, of a long square threaded-screw V with very great pitch, capable of turning easily. The nut A is attached to the upper carbon holder, which will descend slowly when this screw is allowed to turn; the screw is kept from turning by the second nut in the piece BD, which nut can turn only when the friction of the pressure on it, exerted by the piece BD, is released; this is done by the iron cores F in the solenoids; when the current in these solenoids decreases, the iron cores descend and relieve the upper nut, which can then turn and thereby allow the screw to turn and the nut A to descend, feeding the carbons. The two carbon holders both move, being suspended by means of a common cord over pulleys so that as the upper one moves down, the lower one moves up half as fast, thereby keeping the light in one place. The force for bringing the carbons together is produced by a weight, which is pulled up by the act of putting new carbons into the lamp. As it is a multiple arc lamp, the coils are in series with the arc, and no shunt coils are necessary. The lamps are made for a number of different currents, from 3 to 50 ampères. The light is particularly steady. As the arc remains in the same place, a very small white globe, only 6 to 8 inches in diameter (see cut of Bardon lamp below), can be used, which gives a very neat appearance and a very pleasant diffused light. The very small lamps of 3 ampères are an important addition to arc lamps, as it enables such lamps to be used in many cases where the usual large arc lamps would be objectionable.

Bardon.—The lamps of Bardon (French section, silver medal), shown in the following cut (Fig. 6), is interesting on account of its great simplicity. It is one of the simplest arc lamps in use. It consists simply of a brake actuated by a core in a solenoid, and pressing lightly against the circumference of the large wheel seen at the top, which carries a small pulley on its shaft, over which passes the cord on which the carbons are suspended; the weight of the carbons tends to turn this wheel and it can do so only when the brake has been released by a diminution of the current in the solenoid. This regulation is said to be so sensitive and gradual that the wheel is turning slowly all the time; and an ampèremeter in circuit is said to remain quite steady; the feeding of the carbons can not be noticed by it. The lamp is, as usual, for multiple arc distribution, and has no shunt coil. The two carbon holders are, as in many other lamps, both movable, being suspended by a common cord over pulleys so that as the upper moves down the lower moves up through half the distance. This enables them to use very small globes, as shown. The arc is started by the whole wheel being raised by the brake, lifting up the upper carbon with it. The leads to the carbon holders are made with flexible cords and there are no sliding parts which need attention and cleaning.

Pieper.—In one of the Pieper lamps (Belgian section; gold medal) the upper carbon is pushed down by a make and break vibrator actuated by a shunt magnet. The spark produced at the make and break is scarcely visible. In another of these lamps there is a very ingenious escapement to the clockwork mechanism which permits the revolving escapement fan (and thereby the carbon) to move slowly, only; the escapement fan has attached to it a small weight which flies out and strikes against a stop when the wheel turns too fast: this makes the feeding very regular and gradual.

Maquaire.—The Maquaire lamp (French section; silver medal for lamp alone) is interesting on account of its very sensitive regulation and consequent steadiness. It is entirely independent of weights, clockwork, etc., and will run in any position. It is adopted and used by the French Edison Company. The upper carbon rod is actuated by a rack and pinion driven by a small electric motor. The lamp current passes through the magnets; the armature current is controlled by a contact piece resting normally between two contacts by the combined and opposing action of a spring and a magnet in shunt to the arc; when the arc is too short the spring predominates and closes one of these contacts and thereby turns the motor in one direction; when the arc is too long, the

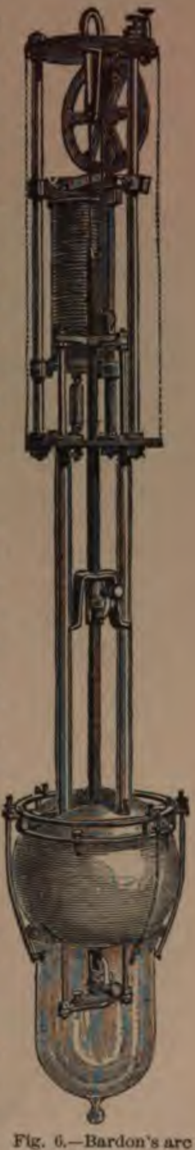
Fig. 6.—Bardon's arc lamp.

magnet predominates and closes the other contact which turns the motor in the other direction. By making the distance between these two contacts very short, the regulation becomes very sensitive. It is made for multiple arc or for series distribution.

The principle appears good, except that for multiple-arc distribution it is not quite rational to actuate the lamp by a shunt coil, because this shunt coil should exert a constant pull or action, no matter what current is in the lamp, as it is controlled by a constant potential circuit. In order to enable a shunt coil to be dependent on the arc, there must be a resistance between the mains and the lamp, which means a waste. In other words, such a system requires as a necessary part of it a dead resistance in which energy is wasted.

Among the other claims are that the lamp is very short. They are usually run two in series on a 110-volt circuit, requiring 8 ampères and 45 volts, leaving a waste of 20 volts, which at 8 ampères gives 160 watts per two lamps, or almost as much as 3 ordinary incandescent lamps; this feature is, however, common to the multiple-arc system and not to this lamp only, except that in this lamp it is essential for the regulation. The upper carbon is cored, and is five-eighths of an inch in diameter and 7½ inches long; the lower is plain, seven-sixteenths of an inch in diameter and 6 inches long; they burn eight hours. The average price of the lamp is $40.

Breguet.—The Breguet "dynamo" lamp (French section) is perhaps the simplest in its principle though not in its construction. It consists merely of a small Gramme motor, with a small pinion on which gears the rack of the upper carbon rod. This constitutes the whole lamp; the weight of the rod tends to turn the motor and its turning force is balanced exactly by the tendency of the motor to turn in the opposite direction. The lamp is only for multiple-arc distribution. The motor is series-wound, but has also an auxiliary shunt winding, the object of which is said to be merely a damper to prevent too rapid a motion.

Aboilard.—In the Aboilard lamp (French section) the upper carbon rod is a long screw, the nut of which is turned by a make and break movement, whereby the rod is fed downward. It is therefore independent of any weights or position, and the regulation is by exceedingly small steps. The current is said not to vary more than one-tenth of an ampère while it is regulating.

Brown.—The Brown lamp exhibited by the Oerlikon Company (Swiss section) is also one of very simple construction. It consists, like a number of others, essentially of a brake which is applied to a large escapement wheel driven by the weight of the upper carbon. This brake is in the form of a wedge which is controlled by being inside of a very large coil of the full diameter of the lamp case. This large coil is intended to act by virtue of its self-induction to prevent too sudden changes in the current, and is therefore to replace the usual external resistance which is almost universal with arc lamps when in multiple arc, and which represents a great waste of energy. As there is a loss of 3 volts in this large coil, it has considerable resistance besides its self-induction. A good illustration and a description of the lamp will be found in l'Electricien, June 22, 1889.

Henrion.—The Henrion lamp (French section; gold medal) is one of the very few lamps exhibited which are usually run in series. The lamp itself is a slight modification only of the so-called and well-known Pilsen lamp. Both his series and his multiple-arc lamps are said to be exactly the same (both being differential) except that the former have a cut-out which switches equivalent resistances in circuit if the lamp fails. Among the multiple-arc lamps there were some of as low as two ampères, of which he claims to obtain six to the horse power. It appeared to burn quite nicely.

Crompton.—The Crompton lamp (English section; gold medal) is another lamp of exceedingly simple construction. It is for series distribution and often of as high as 25 ampères. It consists simply of a brake controlled by a differentially wound solenoid, and acting on a simple wheel escapement run by rack and pinion driven by the weight of the upper carbon holder. They are used very largely in England.

Thomson-Houston.—The Thomson-Houston lamp (United States section) differs from most others in that the carbons are at first separated; when the current is first started the mechanism brings the carbons together and separates them again to form the arc. The series coil is replaced by a spring, as the lamp is for series distribution only, in which, therefore, the series coil can not be used to regulate, as its action is constant.

Thomson.—In the personal exhibit of Elihu Thomson there was shown an alternating-current lamp, one of the very few exhibited. The upper rod having a rack descends by its weight and drives a clockwork mechanism; the escapement of this is stopped or released by a lever having a massive copper disk situated between the two poles of a shunt-wound alternating-current magnet. This copper disk is repelled by currents induced in it; when the current in the shunt magnet increases by the arc becoming too long this repulsion releases the escapement and allows the carbons to descend slowly. It was connected to a peculiar transformer which maintained a constant current in the secondary circuit on being connected to a constant potential primary circuit (see transformers).

Jablochkoff.—The Jablochkoff candle (French section) was the only other alternating-current arc lamp exhibited and one of the very few foreign arc lamps for series distribution. Formerly these lamps, consisting each of five candles, were run with as many wires, so that as each series of candles was burnt down the current was switched on to another series until all five were burnt down. These multiple wires were objectionable and costly. Now they are run as follows: In the bottom of each lamp-post is a *series* transformer through which the constant current of the whole circuit passes. The secondary circuit of the transformer is connected to all the five candles in multiple arc through small lead fuses at the bottom of each. At the top of each candle the two carbons are connected with a carbon cement of high resistance; the current at first passes through all of these in multiple arc and burns out the weakest one which lights that particular candle, the others remaining as they were; the current passing through the others continually, and which is therefore wasted, is insignificantly small. As soon as that candle has burnt down to its holder, the heat of the arc melts the fuse at this point, which cuts out that lamp; the current must then pass through the others, lighting the one of lowest resistance, and so on until all have been consumed.

Sautter, Lemonnier & Co.—The arc lamps of Sautter, Lemonnier & Co. (French section), used for their well-known search-light projectors, are all usually hand regulators, the carbon holders being moved simultaneously by being secured to two nuts on a common screw, one part of which has a right-hand thread and the other a left-hand one of double the pitch. The carbons in these are not directly opposite, as usual, but are slightly out of line so as to form the crater of the arc on one side of the positive carbon, in order that the full light of this crater shines directly onto the reflector without any obstructions. The arc for their large 60 centimeters reflector is said to be of 60,000 candles without the reflector. They find that the maximum light is given with 55 to 60 volts; higher voltage gives even less light. For the smaller 30,000-candle light it is found to be 50 volts.

The Mangin reflector for these projectors, as is well known, is in the rear of the arc and is composed of a lens, the rear side of which is a reflector. The light is therefore refracted twice and reflected once, thereby enabling a smaller lens to be used than if it was refracted only once. All the light from the arc passes back to this reflector; there is no direct light from the arc. The flashes for signaling by means of these projectors, for instance by Morse character, are produced by a small hinged iron screen, which is placed between the arc and the reflector, thereby completely cutting off the light. The following figures regarding these projectors may be of interest: There are 4 sizes, 30, 60, 90, and 150 centimeters in diameter (12, 23½, 35½, and 59 inches, respectively). The power of these is as the squares of their diameters, the third being therefore about twice the second, and the fourth being about seven times the second. Although the rays from the projector should be quite parallel, they do make a small diverging angle, the size of which is one degree and a half; this is due to the fact that the arc has an appreciable size and is not a mere point. There is no spherical aberration, the composite reflector being the equivalent of a parabolic mirror. The formula for calculating the candle power of the beam of light at different distances is—

$$\frac{A^x}{x^2}$$

in which x is the distance and A is a fractional constant depending on the atmosphere; for an absolutely clear atmosphere A is equal to 1. For a moderately misty atmosphere, such as that around Paris, A is about 0.8. For calculating the apparent illumination of a distant place, as seen by the operator at the projector, this formulæ must be squared; as the distance is doubled, it therefore becomes—

$$\frac{A^{2x}}{x^4}$$

in which the symbols stand for the same quantities. With the small 30-centimeter projector the operator can see objects on a clear night 1,000 meters distant (3,280 feet). The arc of the 60-centimeter projector has a candle power of 60,000 candles without the reflector; with the reflection it is increased 1,100 times, or equivalent to 66,000,000 candles. The 150-centimeter projector, which was in operation continually during the exhibition, from the top of the Eiffel Tower, is about seven times as powerful; the direct light from it hurts the eyes even from a distance of several miles. The above figures were obtained from the makers.

Meritens.—In the exhibit of Meritens & Co. (French section, gold medal), who are the well-known pioneers in electrical light-house lights, were shown some carbons 2½ inches in diameter for 600 ampères and 45-volt lamps for light-houses, which are made of a large number of rods of square cross section tied together to form one. They claim that these composite carbons burn more evenly for such large sizes.

Le Blon.—The arc lamp of Le Blon (French section) was practically without any mechanism. It consisted of two carbon holders in the form of two pivoted levers like a pair of scissors held vertically, having carbons fastened perpendicularly at their lower points. The carbons rest against each other at their extremities and glow at this point; their weight feeds them as they are consumed. It should be used with an alternating current. In another form the carbons are curved and are forced together by a weight on a string over pulleys on the holders. It is a question, however, whether a true arc is formed, or whether, as is more likely, it is more of an incandescent light. They were not running, and were probably experimental only.

Puvillard.—The lamp of Puvillard Frères (French section) was somewhat similar, having two curved carbons fed by clockwork, the escapement of which was controlled by a shunt-wound magnet. The clockwork had to be wound up. The two curved carbons were in two different inclined planes, touching at the intersection of these planes. It was a very short lamp, with the arc at the top, to be used as a table lamp.

Arnould.—In the Arnould lamp (French section) the arc is surrounded by two concentric cylinders of glass, the outer one being closed at the bottom. The object is to make the air for the lamp pass down between the two cylinders and become heated before it passes by the arc, whereby it is claimed greater efficiency is obtained.

Dulait.—In the lamp of Dulait (Belgian section, gold medal) the position of the carbons is reversed, the postive or bright one being the lower, so as to throw the light up against a conical reflector. The principle is that if a light is diffused over a great surface the pupils of the eyes of persons do not contract as they would if the light were all from one small point, and that, therefore, less light will be necessary to produce practically the same illumination as far as the eye is concerned. It furthermore illuminates to greater advantage, as it casts no dark definite shadows. He claims that the gain in this diffusion of the light is greater than the loss attending the reflection, and as a result a smaller number of such lamps is required in replacing the usual lamps by these.

Alioth.—The Alioth lamp (Swiss section) is claimed to burn fourteen hours with one set of carbons, although they are only about 8 inches long. The upper one has a cross section more than twice that of the lower. The upper one is always cored. It is not stated to what this long life of the carbons is due, but it is presumably owing to its being a small current lamp.

References.—For carbons see "General supplies." For "illuminated fountains" see "Miscellaneous applications of electrical energy." For "systems of distribution" see under that heading.

INCANDESCENT LAMPS.

Development.—The introduction of the incandescent lamp as a commercial lamp may be said to have begun between ten and twelve years ago, although it was known and had been used a number of years prior to that, yet it had not been developed sufficiently to come into general use.

One of the most important steps in its development, made at that time, was to make the incandescent carbon long and slender instead of short and thick; this was without doubt that which made it a practical success as a commercial lamp. This step is claimed to have been made by Edison. After the very rapid development of the first few years of its introduction, but little progress has been made other than minor improvements in details of construction and manufacture, which naturally accompany the manufacture of any article on such a great scale. The potential almost universally adopted is about 100 volts. The efficiency has been increased but little in the last five or six years; it is at present as a rule between 3 and 3.5 watts per candle for the usual lamps, and in some cases as low as 2 watts for large lamps with thick filaments.

As a converter of electrical energy into light, it is still very inefficient; an arc lamp will give from five to ten times as much light per watt as the incandescent. It is claimed to have been found that only a very small fraction of the electrical energy of an incandescent lamp is converted into light, almost all of it being converted into heat. If this is the case, and it seems likely, it is a great waste of energy to produce light with incandescent lamps, in the same way as it is a great waste to use gas for illuminating purposes, or even to use coal for driving steam engines. There is therefore very much room for improvement of incandescent lamps, which will probably be in its being replaced by a radically different lamp, rather than in improvements of the present form. Some development in this direction was shown by the small arc lamps of low candle power, requiring as little as two ampères. But although the latter have such a very much higher efficiency, yet they do not compare to the incandescent lamp in convenience. The latter feature is of such great value in favor of the incandescent lamps, that the arc lamps are even being replaced to some extent by large incandescent lamps of 1,000 and 2,000 candles.

Another direction of development shown is in the radically different incandescent lamp exhibited by Pieper, which belongs to the so-called semi-incandescent lamps, though it is truly an incandescent and not an arc lamp. This lamp is said to require only 1 watt per candle. Among the incandescent lamps exhibited were some Khotinsky lamps of 150 to 200 volts and of the usual candle power. If these are in all other respects as good as the usual 100-volt lamp it is an important advance, as it cheapens the distribution very greatly.

The manufacture of incandescent lamps is at the present time already one of the largest branches of the whole electrical industry; several makers in France alone claim to be making lamps at the rate of 2,000 and 1,000 per day. In Germany, as also in England, the quantity is doubtless still greater, while in the United States there are probably as many made as in all the other countries combined.

Exhibits by countries.—There were altogether about eleven exhibitors who manufacture the lamps themselves. Of these, three (Edison, Thomson-Houston, and Heissler) were from the United States, the rest were almost exclusively from France, though the inventors of some were from other countries.

DETAILED DESCRIPTION.

As the processes of manufacture are usually—and wisely, too—kept secret, the following detailed description is limited to a mere mention of some of the data of the respective lamps:

Edison.—In the Edison exhibit (United States section, grand prize for whole exhibit) there was shown a well-arranged and complete exhibit of the various steps in the manufacture of the lamps, from the crude material to the finished lamps. There were stated to be twelve hundred varieties of bamboos, of which three hundred are useful. A particular one of these found in a certain hilly district of Japan, after a certain age of growth and seasoning, was found to be the best and is the one at present used. The inner pithy fibers and the hard, siliceous outside are planed off, leaving the inside, from which the straight filaments, with their widened terminals, are cut to an exact size. These are then bent, carbonized, and connected to the leading-in wires by electrically deposited copper.

Lamps are made of 4, 6, 8, 10, 13, 16, 20, 24, 32, 50, 100, 150, 250 candle power, all for the same circuits of about 110 volts. The lamp manufacture has become a very large part of their industry. Some idea of the extent of this may be had from the fact that at the close of the year 1888 they had 434,181 lamps installed in isolated plants alone, which was almost double that of the preceding year, 230,674. Besides these there were 675,660 lamps in central stations and 15,550 in municipal plants, making a total of about 1,125,000.

French Edison-Swan lamps.—Probably the next largest lamp manufacturers of those exhibiting is the Compagnie Générale des Lampes Incandescentes (French section, gold medal), who manufacture under the combined Edison and Swan patents in France. Their capacity is 2,500 lamps per day, employing 200 hands and using 250 horse power. They make chiefly two styles of lamps, one with a plain horseshoe filament like the Edison, and one with the filament in the characteristic loop form of the Swan lamp. Their usual lamps are made for 10, 16, 32, and 50 candles; they have also introduced larger ones of 100, 200, 500, and 1,000 candles. They are made of various voltages from 2 to 200 volts, at an efficiency of from 2 to 4 watts per candle; the types generally used consume 3.5 watts per candle, while the larger ones require only 3 watts; the life is said to be 1,000 hours. For special cases in which greater economy is desired at the expense of life, the consumption is reduced to 2 watts per candle, with a life of 500 to 600 hours.

The large lamps of 1,000 candles are introduced to replace the arc lamps, which are objectionable in many cases. The cost of such a lamp is $6.75, and assuming a life of 800 hours, this corresponds to 0.85 cent per hour for the cost of the lamp; the cost of the consumption of carbon alone in an arc lamp they give as about 2 cents per hour, showing considerable saving in favor of the incandescent lamp. Besides this there is the cost of the arc lamp and the cost of attendance, which is by no means small. On the other hand, the consumption of power for arc lamps is considerably less, being only about one-half watt per candle, as against 3 watts for the incandescent. Besides this the cost of the circuit and of the transmission of the same amount of power for arc lamps in series is less, but in Europe they usually run arc lamps on the usual multiple arc circuits, so that this factor does not enter there. They also make focus lamps to be used with reflectors, for search lights for instance, in which the filament is in the form of a closely wound spiral, so as to have the light as nearly as possible condensed in one point.

Gabriel.—Another large exhibition of lamps was that of F. Gabriel. (French section, honorable mention.) He claims 3.5 watts per candle for the usual sizes and down to 2.5 for the larger ones, at 800 to 1,000 hours. The filaments are made of gun cotton. The base is of a black glass or enamel, with a bayonet clamp or holder and two exposed flat contact surfaces on the bottom, making a very simple and practical lamp base, which is used also by a number of other makers.

Lodyguine.—Lodyguine, who was one of the earliest, if not the earliest worker in this field, has a small historical exhibit in the Russian section (gold medal), showing chiefly the various substances with which he had made lamps. Among these were caen cloth, raw flax, silks, broom weed, lime-tree wood, fiber from the dwarf palm leaves. The material used now appears to be couch grass or weed grass. The joint of the carbon with the leading-in wires is made of a carbon cylinder having the wire twisted around the outside and the filament inserted through the center.

Cruto.—The Société Anonyme pour le Travail des Métaux (French section, silver medal) exhibited the Cruto lamp, which is made of a fine platinum wire, on which the carbon is deposited by heating it in a hydrocarbon gas. An interesting novelty was a glass bulb for the lamps, which was corrugated, or formed with numerous ridges, small projections, and depressions, in such a way that the light from the filament was broken up into a large number of bright points and was thereby diffused as in the usual ground glass or milky bulbs, but without suffering any loss, as the glass was quite transparent.

Gérard.—The Société Anonyme d'Électricité (French section, gold medal) exhibited the Gérard lamp, in which the filament is made of two straight carbon rods cemented together at their upper ends. The rods are made from a paste like arc-light carbons. They are mostly for low voltages varying from 6 to 33 volts, and up to 100 for the very large lamps. Their efficiency is stated to be 3 watts per candle.

Khotinsky.—Daniel Augé (French section) exhibited the lamps of Khotinsky. This is the only lamp exhibited which is made for as high as 150 and even 200 volts, and as small a current as 0.16 ampères for small candle powers down to 5 candles, with the usual efficiency of 3¼ to 3½ watts per candle. If these lamps are as good in life and mechanical strength as those usually made, it is a very important and valuable improvement, as it reduces the size of the conductors to one-half and one-fourth of that required by the usual 100-volt lamps. They claim to make 2,000 lamps per day, employing 300 hands.

Sunbeam.—The "Sunbeam" lamp, exhibited by A. Janssens (French section, silver medal), is a large lamp for from 150 to 2,000 candles, with an efficiency of from 2 to 2.5 watts per candle, the chief use for which is to replace the arc lamp. For 800 candles and less it has one filament, and for greater candle powers there are two filaments in derivation in the same bulb.

Pieper lamp.—One of the most interesting lamps, on account of its simplicity and novelty, was the Pieper lamp (Belgian section). It consists essentially of two copper rods about like lead pencils, secured one opposite to the other like the two carbons of an arc lamp, only that they are horizontal. Their ends are separated by a small space of about an eighth of an inch, as if to form an arc between them; their other ends are supported by springs so as to allow for a slight upward motion of the free ends. One of these is connected to the positive and one to the negative pole of a circuit. Over the small space separating the ends of these rods, where an arc would otherwise form, rests a vertical carbon rod which touches both of these ends and forms a bridge over them; the current therefore passes over this space through the end of the carbon rod, thereby keeping it at a white heat; as the carbon burns away it feeds itself by its own weight, it being held in a vertical tube. There is, therefore, no regulation of any kind necessary, and the whole mechanism is reduced to an exceedingly cheap and simple device. Should the carbon rod break off, or refuse to feed down, the ends of the two copper rods will move up until they touch a metallic bridge piece which thereby short-circuits the lamp to prevent its interfering with others in series with it. The carbon rods are of special construction, resembling two thin rods united together on one side, quite similar to a Jablochkoff candle, only that they are entirely of carbon.

The following figures were given by the exhibitor and are said to have been taken from an expert test: With 10 volts and 20 ampères it gave 200 candles, which corresponds to an efficiency of 1 watt per candle, or from two and a half to three times as good as an incandescent lamp. The carbon is consumed at the rate of 2 inches per hour, one carbon lasting eight hours. It appears to be quite new, and there was, therefore, no opportunity to discover any weak points. It is a question how the copper will stand the heat; it is supposed to conduct the heat off rapidly enough to prevent the copper points from being injured. For an illustration of the lamp, see Industries, September 13, 1889.

References.—For systems of distribution, see under that heading.

SYSTEMS OF TRANSMISSION AND DISTRIBUTION.

General.—Apart from the exhibits in the United States section there was very little at this exhibition which was of novelty or importance in systems of transmission and distribution of electricity. In the United States section there were more different and distinct systems exhibited than in all the other sections together. To an American it was strange to see how little attention was given to this subject abroad, if the exhibition can be said to represent the state of the art there. Almost the only system in use there for lighting seems to be the multiple-arc system in its original simplicity. Series systems, or the more complex systems, or those in which there is a conversion, were limited to a very few isolated exhibits of less importance. This may be partially due to the fact that they are averse to high-tension currents on account of their danger to life, and that they hesitate to introduce any improved system until it has been well developed and introduced by the less conservative Americans. England alone appears to be an exception. One of the characteristic features of the United States exhibits was that they were developed in all details with all necessary accessories to make the system complete and practical. In complete systems of transmission and distribution, America had more to teach than it had to learn at this exhibition.

Incandescent lamp distribution.—Aside from the United States exhibits described below, the only systems exhibited in operation were the simple multiple-arc distribution, the three-wire system, and an unimportant converter system. In one case several small incandescent lamps were run in series on multiple-arc mains, but as there was no cut-out or regulating device of any kind, it can not be called a system. Series distribution of incandescent lamps, of which there were three American exhibits, seem to be almost unknown in France. Even the simple three-wire system does not appear to be used very much, and the alternating converter system, though used, was not exhibited in operation outside of the United States section. For some introductory notes regarding the latter system see "Transformers."

Arc lamp distribution.—In the European exhibits, arc lamps were almost universally run on the same multiple-arc circuits as the incandescent lamps; in those cases there was one lamp on a 75-volt circuit or two in series on a 100-volt circuit; in either case there was almost always a dead resistance in circuit, in which from 20 to 30 per cent of the power is wasted. The advantages claimed for such a distribution are that the arc lamps may be on the same mains with the incandescent, and that the potential is therefore as low and safe as that for incandescent lamps. The great advantage which our usual series distribution has over it, besides the economy of power, is the considerable saving of wire, not only in size but also in length, as in many cases the series circuit is single, while the multiple-arc circuit must always be double. The multiple-arc system has the advantage that the lights are less dependent on each other, but in any good series system, as installed by the better companies here in the United States, there is very seldom a complete failure all along the circuit, due to one bad lamp.

For a further comparison of these two systems see the paragraphs on series lamps and multiple-arc lamps, under the heading "Arc lamps." With the exception of the Jablochkoff candle system and one or two less important exhibits, the series arc-light systems were limited to two from the United States (Thomson-Houston and Sperry) and one from England (Crompton). There was nothing of novelty in any of these, and their description has therefore been omitted. The almost total absence of this cheap and convenient system among the European exhibits was very noticeable to an American.

Power transmission and motor distribution.—Apart from the exhibits in the United States section, there was scarcely a single exhibit of importance of a complete system of distribution of independent motors. There were quite a number of transmissions of power by means of motors, but they consisted of a single generator driving a single motor, and therefore can not be called a system of distribution. The generators and motors were generally both series-wound machines, the motor being started by means of an auxiliary resistance in series with it, which was gradually cut out as the motor reached its proper speed. In one of these "systems," the well-known name of which need not be mentioned here, some of this resistance was at the generator station and had to be kept in circuit all the time.

In the distribution system exhibited by the Thomson-Houston Company the motors were run from the usual multiple-arc circuits. The motors were shunt wound, and were started by a switch which first put the field into circuit, then the armature in series with a resistance, and then gradually cut out this resistance as the speed increased to its normal value. The reverse operation stops the motor. As the results from opening the field circuit first might be very disastrous to the motor, this switch forms an essential part of such a system.

Railroad systems.—The electric-railroad exhibits were limited to two very good ones from the United States and one from Belgium. When compared with the large number of electric railroads in the

United States, those in Europe are so few in number that this branch of electrical engineering can hardly be called an important industry there.

DETAILED DESCRIPTIONS.

Edison system.—In the exhibit of the Edison Company were shown many of the details of their regular multiple-arc three-wire system. As this has been so fully described in the technical journals and is so well known here in the United States, it is not necessary to describe it. It might be mentioned here that the balance of the lines is effected by means of very large resistances of iron wire at the station, which are in the form of spiral coils, so grouped and connected to the multiple-contact switch that by moving the switch lever to successive contacts the same coils are variously grouped in multiple-arc or series, according as the current is greater or less, the total successive resistances varying in regular steps. By this means of always using all the coils much wire and space are saved, as the current capacity must sometimes be very great. Some of the special instruments used will be found described under "Instruments."

Five-wire system.—A descriptive note of his five-wire system states that "any lamps of one branch may be thrown upon any other branch to equalize the load, the controlling apparatus being in the center station." The way this was done was not, however, described, nor was the system exhibited.

Municipal system.—The Edison municipal system of incandescent lighting in series is for streets, parks, public squares, etc., in which the number of lamps burning is approximately constant. The dynamo has 1,000 to 1,200 volts. The circuits from it are in several multiple-arc branches, of 3 ampères each, and are kept constant. Machines are made for four, eight, and twelve circuits. In each of these circuits all the lamps are in series. Each lamp has an automatic cut-out in its base, which short-circuits the lamp in case of breakage or failure. At the station each circuit has its ampère-meter, which rings an alarm if current increases, due to the cutting out of a lamp. The attendant then switches a lamp into that circuit at the station to restore the balance. The lamps on the same circuit may of course be of different candle power, and may be rated at about 1 volt per candle, making about 1,000 candles per circuit. Some of these circuits are 10 miles in length; they are of No. 12 wire.

Thomson series incandescent system.—The Thomson-Houston Company exhibited a system of incandescent lamps on series circuits. The only special peculiarities are that the act of screwing in a lamp opens a switch in its base which otherwise short circuits it. In order to cut out a lamp which fails while burning, there is in each base a spring contact which is insulated only by a thin piece of paper; should the lamp fail, the potential developed at its poles, that is, at this contact, would momentarily rise so high as to pierce the paper, thereby making contact and short circuiting the lamp.

Heissler.—In the Heissler system (United States section, gold medal) the alternating current machine has two independent circuits of 5 ampères each. These are kept at a constant current strength. In each of these there are 5-ampère incandescent lamps in series and of different voltages depending upon the candle power. They are all supposed to be kept burning at one time, though a few may be turned off in each branch independently, or any desired number if the same number is cut out in each branch.

A double regulator run by a small belt, and operated by two series magnets, one in each circuit, switches a resistance into and out of each of the two main circuits to regulate the currents independently, that is, to balance them; it also regulates the exciting current of the dynamo when both circuits are to be adjusted in the same direction. The dead resistance is, therefore, used only when there is an inequality in the two branches; whenever both vary the same, the exciter is regulated. The regulator performs both of these operations automatically. Each lamp has a small cut out in its base, which consists merely of a small electromagnet, which will short circuit the lamp if it should burn out or be broken; it operates equally well if the lamp is broken or removed before the current is started, a case in which some other systems fail.

The filaments of the lamps are all the same diameter, but vary in length, depending on the candle power. The filaments being much thicker than usual with 100 volt lamps, they are less frail and can be run at a higher temperature and therefore at better economy, from 2.5 to 2 watts per candle. The chief application is for long distance transmission and for buildings and places in which the number of lamps burning is not varied very much. Its advantages are its simplicity, the great saving of wire for long distances, and the greater efficiency of the lamps.

Multiple series system.—The Thomson-Houston Company exhibited a multiple series incandescent system, in which the incandescent lamps are run in groups of several in multiple arc, the groups being in series on the usual series distribution system, with arc lamps. Each lamp has in its base a cut-out and a resistance equivalent to that of the lamp. Should the lamp fail, the cut-out will automatically switch this resistance in the circuit to replace that of the lamp. The resistance is ingeniously arranged on small pieces of mica so as to take up as little room as possible in the base of the lamp, and at the same time to cool off as freely as possible.

Accumulator.—The Société Anonyme pour la Transmission de la Force par Électricité exhibited a system in operation in which the dynamos for direct lighting in the evenings were used in the daytime for charging accumulators, whose current was then available in the evening or at any time during the day. The cells were in several series groups, which groups were connected in multiple arc. The last twelve cells of the series were connected separately to a twelve contact switch board, by means of which one after the other could be added or cut out to keep the potential constant. There was such a switch board for each of the multiple arc circuits leading off from the accumulators, but all were connected to the same twelve regulating cells.

Transformer system.—The Thomson-Houston Company exhibited their alternating current transformer system. The transformers were in multiple arc on the primary, having 1,000 volts. The transformers reduced this to 50 volts. The system itself did not differ materially from the usual one, and therefore needs no description here. For a description of their transformers see under that heading. The French Edison Company use for long distances the Zipernowski-Deri-Blathy system of alternating current transformers. The primary has 1,000, 2,000, or 3,000 volts, and the secondaries 100, 75, or 50. The system was not exhibited in operation.

Thomson Compensating system.—The only system of distribution exhibited which was quite novel in principle was the ingenious one of the Thomson-Houston Company called the "compensating" system. It is for the general distribution of incandescent lamps by alternating currents, permitting any to be turned off at will. The object is to reduce the cost of wire from the dynamo to the centers of distribution. The general arrangement is shown in the adjoining cut, Fig. 7.

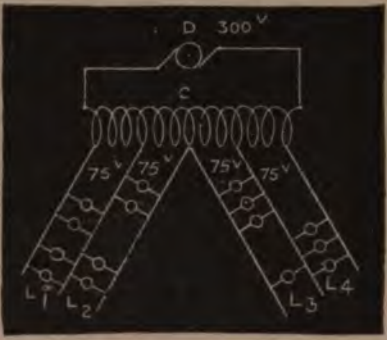

FIG 7.—Diagram of the Thomson compensating system of distribution.

The self-induction coil C is like an ordinary transformer, but with only a single coil. Branch wires lead off from the ends and from three points in the coil, as shown, which form two three-wire systems of distribution for 75-volt lamps. This coil is placed at the center of distribution of that set of lamps, and is in multiple arc with others like it, across the 300-volt mains from the dynamo. The four sections of this coil each act as a compensator for the lamps in multiple arc with it. Each section will keep the potential of its lamps constant, no matter how many are turned off, and it will furthermore be independent of any of the other sections.

The power consumed is said to be proportional to the number of lamps burning, as the apparent loss of current in the coil is not a real loss of energy. There must be some loss, however, when all the lamps are turned off, but how much the writer could not ascertain. It was stated that the efficiency was 95 per cent. but this is probably when the full load of lamps is running.

The dynamo for supplying the current was interesting on account of its being a compound wound alternating current in which the alternating current was redressed, passed through the series coils and redressed again (see dynamos). This system permits therefore of running 75-volt independent lamps with a 300-volt current of one-quarter the strength in ampères, thereby reducing the weight of the feeding leads to one-sixteenth of what it would be in the simple multiple arc distribution. Such a direct comparison is, however, misleading, as the disposition would be chosen differently if the ordinary system were to be used, thereby reducing this apparently very great difference somewhat, but nevertheless leaving a great margin in favor of this compensating system.

Long-distance transmission.—Another ingenious system was exhibited by the Thomson-Houston Company for transmitting current to a distant center of distribution. It was in operation for transmitting and distributing power and light to the American agricultural exhibits, situated several thousand feet from the generator. It was the only exhibit in operation of a true system of distribution of light and power at a distant center; the only other exhibit of long-distance transmission was merely a simple series system in which the motor was used to drive a line of shafting, there being, therefore, no distribution other than that by shafting.

This Thomson-Houston system consisted of a 220-volt generator, a long-distance two-wire transmission to the center of distribution, and a special redistribution which changed this two-wire circuit into a three-wire one of two branches of 110 volts each, from which lights or motors were run as usual. This redistributor consisted of a single motor-dynamo having two windings and two commutators on its armature; these two armature circuits were connected in series with each other, the double motor being then run as usual from the 220-volt circuit, the single field being in shunt. The three-wire circuit was connected to the poles of this motor, the neutral wire being connected to the junction of the two armatures. This divided the 220-volt circuit into two branches of 110 volts each; the double motor, by virtue of its action, both as a motor or a dynamo, keeps the two circuits balanced and at a constant and equal potential, no matter how many lamps are turned off.

Oerlikon power transmission.—In the system for the transmission of power exhibited by the Oerlikon Company, which is being introduced extensively, especially in Switzerland, there is one generator and one motor, both are series wound and are connected in simple circuit. The largest machines used are from 250 to 300 horse power, which were the ones exhibited. (See Dynamos.) For greater power they use two or more generators and the same number of motors, the transmission being then on the principle of the three or more wire system.

The system is said to be self-regulating for variable load without any additional regulator, both machines being series wound. The only difficulty seems to be in starting the motor, which must be done slowly and carefully. They always have telephone connection between the two stations for this reason. The motor is readily stopped by opening the circuit at the motor or by short-circuiting the field of the generator. As there can be but one motor in such a system, it is limited to power transmission, as distinguished from power distribution. For a report of a test made of such a system in operation, see La Lumiere Électrique, 1888.

ELECTRIC RAILWAY SYSTEMS.

There were three systems of electric railways exhibited, the Thomson-Houston and the Sprague from the United States, and the Julien from Belgium.

Thomson-Houston.—The one exhibited by the Thomson-Houston Company included a full-size truck and all details and accessories for the transmission. The system was one with a single overhead wire and trolley, the ground being used as a return. The exhibit was quite complete in all details, including the systems of overhead conductors, with its crossings, switches, trolley, etc. There was one motor for each of the two shafts; the fields were wound in sections; the controlling switch included a series of resistances made of plates of iron closely clamped together, which served to start the current gradually. At the end of this switch where the current was broken there was an ingenious device, consisting of a magnet, which acted to "blow" out the spark produced on opening, the magnet being itself put into circuit by the switch. The reversing switch was separate. The motors were pivoted on their axles, and at the other end were secured by rubber cushions, allowing for a slight play. The brakes were of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. There was an intermediate shaft and a [illegible] of [illegible] gear wheels. Those on the main shaft were [illegible] [illegible] [illegible] [illegible], the pinions were made of alternate layers of [illegible] and [illegible] [illegible] of an iron block. The bearings were [illegible] by a [illegible] [illegible] which was [illegible] [illegible] [illegible]. The [illegible] motor gear was protected from dust by a casing of sheet zinc. The [illegible] [illegible] [illegible] [illegible] first start; the trolley wire was [illegible] as a conductor by a [illegible] [illegible] was [illegible] [illegible] [illegible] [illegible] [illegible]. The [illegible] [illegible] [illegible] [illegible] [illegible] in a [illegible] [illegible].

Sprague.—The [illegible] of the Sprague system [illegible] [illegible] [illegible] head trolley-wire construction, including the trucks and the motors.

There were two motors, one for each shaft, suspended on the shaft at one end and on springs at the other. There was one intermediary shaft. The motor pinions were of vulcanite, to avoid noise. The gears on the main shaft were split, and those on the others were on the projecting ends of their shafts so as to facilitate their removal. The brushes were of carbon, partly tangential, fixed in position, and with spring feed. The fields were wound in sections. The controlling switch or commutator for starting and reversing was of special construction, consisting of a succession of contacts on the surface of a cylinder, representing the sections of the field, the armature, and the line; by turning this cylinder the current was switched to the field sections grouped in various ways from multiple arc to series, so as to start the motors gradually. The oiling was done with fat or tallow.

Julien system.—The Julien system was for use with accumulators. It consisted of a complete car and a separate truck. The front end of the car rested on the pivoted driving truck having four wheels; the rear end rested on two fixed wheels, as usual. The truck had one series wound motor whose pinion geared with an annular wheel with wooden teeth; this was on the same shaft with two pinions which geared with chain gearing to the two truck shafts. The motor develops 3.5 effective horse power. The brushes were fixed and were made of copper foil. The battery consisted of 120 Julien cells under the seats. The starting and reversing was done by one switch, and the changing of speed by another. The latter was accomplished by different groupings of the cells, in multiple arc, multiple series, or simple series, in such a manner that the electromotive force could be varied without losses in dead resistances and that the cells should discharge equally.

Accessory.—Van Vloten, in the Belgian section, exhibited a small model of a very complete system for shifting the boxes of accumulators out of and into the car. It consisted essentially of a roadbed of rollers, on which the boxes could be moved readily, parallel to the car, thence into the car by means of turntables and a short truck, which could be raised or lowered slightly to the exact height of the car.

INSTALLATIONS.

All the parts, including systems, which compose an installation having been described under their proper headings, there remains to be mentioned here merely the installations, as such. Although there were many of these, they were almost all so small and simple that there is nothing left to describe. A few of them were more of the nature of a central station; but as it can hardly be expected that central stations in all their details be erected for the short period of the Exhibition, it would not be fair to judge these as model central stations, for, as such, most of them could not be criticised favorably in many of their features, at least from an American point of view.

With the exception of the accessories of central stations, exhibited in the American and English section, the chief installations were all French. The best and most complete exhibit in operation was that of the Continental Edison Company (French), and this may be said to be a good model of a central station in almost all of its details. Most of the other large installations in operation may serve very well their purpose at the Exhibition, but they can not be considered favorably as standard models of a central station for general distribution, complete in all details. In general, they may have been designed well enough for the particular service for which they were intended, provided no accidents happen, but there was not sufficient flexibility in the installations to meet the requirements of a central station for general distribution, such, for instance, as provision against accidents, stoppages, provisions for reserve power, repairing, extensions of the system, etc., without which a central station does not deserve its name.

Most of the larger installations at the Exhibition were described and illustrated in the numbers of the (London) Engineer for the latter half of 1889, and it is, therefore, thought unnecessary to do so here, especially as such a description would be of little value unless it is a very detailed one, as it is the details which make a central station.

Almost all the wiring in the Exhibition grounds was underground, either by means of lead-covered wires laid directly in the ground, or by rubber-covered wires in troughs, and in some cases directly in the earth, or by provisional wooden conduits, in which they were supported on insulators. The wiring in the buildings was hidden very neatly so that it was not noticeable.

The central station of the Compagnie Continentale Edison was by far the most complete exhibit of a model central station. An illustrated description will be found in the Engineer, October 4 and 11, 1889. It resembled in many respects, in its completeness, a typical American central station, and showed, in its general arrangement and details, considerable experience in central station work, which can not be said of a number of the other large installations exhibited. The distribution was by means of a three-wire system only, with tandem dynamos. It differed from the usual system of universal mains, in that the more important centers of distribution were connected to the station by independent mains with separate switches; the loss allowed was 10 per cent. Arc lamps were run four in series between the 200-volt mains.

The central station of the Société Anonyme pour la Transmission de la Force par l'Électricité included a large installation of accumulators which were charged in the daytime by the engines and dynamos which would otherwise be idle. In the evening they added their stored energy to that from the dynamos direct, thus increasing the capacity of the station. This system is described under "systems." Their central station in Paris is to be operated on a similar system.

The station of the Société l'Éclairage Électrique comprised a number of independent systems, including a continuous-current three-wire system, a direct and a series transformer system for Jablochkoff candles, motors, etc. It was more in the nature of a general exhibition of their various systems, rather than a typical central station for general distribution, from which latter point of view the station could hardly be considered very favorably.

The small installation of Crompton & Co. (English section) was no doubt the most compact installation at the Exhibition—that is, having the greatest output for the smallest floor space, and included a one-third reserve force. It was, furthermore, one of the very few installations of a series arc lamp distribution. There was also a small batch of incandescent lamps on a three-wire system from 220-volt dynamos in multiple. An illustrated description will be found in the (London) Electrical Engineer, August 2, 1889.

LIGHTING OF THE EXHIBITION.

The opening of a large part of the Exhibition in the evening necessitated its being lighted. This brought up the question of how and by whom it was to be done and how it was to be paid for. It was finally decided to give the exclusive right to a French syndicate, which was to receive in return in the neighborhood of half the receipts from admission in the evenings. Shortly before the opening of the Exhibition, and after most of the preparatory work of this syndicate was finished, a change in the financial management of the Exhibition compelled the syndicate to sell their right to a share of the admissions back to the administration for a fixed sum.

The area lighted was to be about 300,000 square meters (3,200,000 square feet) with about 150,000 carcels (1,500,000 candles) using about 3,000 horse-power. It was intended that the lighting should be done by numerous companies from different countries, but, as a fact, it was done almost exclusively by the larger French companies. It was for this reason that the United States exhibitors were excluded entirely and were compelled to keep their lights within their own floor space, and not contribute them to the general lighting of the buildings and grounds.

There were, in all, nineteen different installations contributing to this lighting—eleven of them were French, three were Belgian, two Swiss, two English, and one German; there were none from the United States. By far the greater proportion of the lighting was from the French companies. The number of lights installed by the syndicate was as follows: Arc lights, 739 at 8 ampères (1,000 candles), 104 at 25 (3,500 candles), 48 at 60 (10,000 candles), 146 Jablochkoff candles (400 candles), 16 lamps soleil (1,000 candles)—total 1,053 arc lamps. Incandescent lamps: 5,400 at 4 candles, 3,209 at 10, 240 at 16, 154 at 20, 72 at 500—total 9,075 incandescent lamps. This makes in all about 176,037 candles, at a consumption of about 4,000 horse-power. There was, besides this, some gas illumination, but it was small as compared with that from electric lights, except on special fête days, when certain decorative effects were produced for which the number of gas jets amounted probably to hundreds of thousands. A very good summary of the organization and operation of this syndicate will be found in the Memoires de la Société des Ingénieurs Civils, April, 1889, in an article by M. de Bovet, director of the syndicate. Another article regarding this, by Fontaine, will be found in the Bul. Soc. Internationale des Électriciens, February, 1890, No. 65.

LIGHTING OF PARIS.

For the general distribution of electric light and power in Paris the city has been divided into sections, each one of which is given to an electric lighting company who has the exclusive lighting of that section, under conditions, restrictions, and limitations imposed by the municipal authorities. The work is in progress, some stations being already in operation. For a well-illustrated article on this subject see La Lumière Électrique, June 29, 1889.

The great scarcity of electric lighting in Paris, at present, is due to a great extent to the almost prohibitory conditions imposed by the city, in the form of a very high municipal tax on the power which is used for electric-lighting purposes. The reason for this is that electric lighting would otherwise, to a great extent, replace gas lighting, which is in the hands of monopolists holding important privileges, who share their profits in a certain proportion with the city. As their profits are very great under the conditions, the city receives an important revenue from this source, and it would be diminishing this revenue as well as that of the gas companies to allow electric lighting to replace gas. Furthermore, the "octroi," or municipal tax, on coal used within the limits of the city is very high, and electric-lighting companies are not exempt from it as manufacturing companies are. If the electricity is generated outside of the city limits and led into the city an equivalent duty is imposed on the energy used. An authority states that their company has to pay 5 per cent of their receipts (not profits) to the city when the station is inside of the city limits and 7 per cent when it is outside. The charges of one of the companies in Paris are from 21 to 29 cents per kilowatt hour, which is about 16 to 21 cents per horse-power hour of current; tl [illegible] delphia, for instance, is 7 cents per horse-power hour. For some additional figures regarding this subject see under the heading "Progress" in the Introduction.

STATISTICS.

The Edison Electric Light Company publishes the following statistics regarding their installations. At the close of the year 1888 they had installed in the United States 1,504 isolated plants, having 433,476 lamps; 200 central stations having 675,660 lamps; 23 municipal plants (high-tension series system) having 15,550 lamps. Total, 1,727 plants and 1,124,686 lamps. Their representative states that they have installed 650 miles of underground wire, equivalent to 217 miles of Edison tubing.

The Thomson-Houston Company up to same date had installed 406 arc light central stations having 51,621 lamps, and 170 incandescent central stations having 120,380 lamps; also private plants amounting to more than 20,000 arc lamps and 100,000 incandescent lamps. In 1888 they started to install electric railroads; in one year they had installed 21 lines having 3,000 horse power, and in June had in construction 23 other lines representing 3,000 horse power additional. The Continental Edison Company (French) state that they have installed in France alone 1,500 installations of 100,000 lamps, representing 22,000 horse power.

For some additional statistics see under "Progress" in the Introduction.

ACCESSORIES.

AUTOMATIC REGULATORS.

The regulators exhibited were almost exclusively for automatically varying a resistance in series with the shunt-wound magnets of a dynamo in order to keep the potential of the circuit constant. Compounding the magnets will accomplish this as far as changes in the current strength are concerned, but it will not correct for variations in the speed of the dynamo, which is very important; regulators have for their object to correct for changes in potential no matter what their cause.

In the general type of regulators of this kind there are three essential parts, a resistance arranged in progressively increasing steps, an intermediate mechanism for connecting more or less of this in circuit, and a detector which detects changes of potential and operates this mechanism accordingly. The detector is connected across the mains either at the dynamo or at the center of distribution, according to where it is desired to keep the potential constant. In those exhibited by the Société Suisse pour la Construction de Locomotives et de Machines (Swiss section), and by the Société Alsacienne de

Constructions Mécaniques (French section), which were almost identical, the detector is a solenoid with a movable core; this is attached to a balanced horizontal bar, the other end of which carries a mercury cup which is thereby raised or lowered. Into this dip a series of copper wires of progressively increasing lengths, so that more or less of them will be put in or out of the circuit by the moving mercury cup; these wires lead to the resistances.

In the following regulators the detector magnet operates two contacts, one when the potential is too high, and one when it is too low. The circuits controlled by these two contacts then operate the intermediate mechanism. All these have the fault in common that these contacts require cleaning and care, and at best are very apt to cause trouble.

In the Edison form the mechanism is operated by two magnets which move a common armature lever over a series of sliding contacts representing the resistances.

In the Oerlikon form it is done by a sliding contact moved over the resistance contacts by a long screw shaft. Opposite to the ends of this screw are two magnets whose cores are kept revolving in opposite directions by belts; these magnets are controlled by the detector. A circuit in one or the other causes the screw shaft to be coupled to its core by magnetic attraction; this turns the screw in that direction until the magnet current is broken again by the detector.

The Picou (French Edison Company) form is similar to this, only that the shaft is turned in either direction by a small electric motor controlled by the detector.

The Borssat form is similar to this, only that the shaft is turned very slowly by a worm wheel, and it has on its surface a raised spiral of very great pitch, which touches successively the spring contacts of the resistances.

In the Henrion form, which is identical with the Weston, the sliding contact for the resistances is moved in opposite directions by two ratchet wheels. The pawls for these are kept moving to and fro by a lever operated by a pulley and belt. Two magnets controlled by the detector contacts raise or lower one or the other of these pawls, thereby causing one or the other of the ratchet wheels to be turned. A similar device is used to move the brushes of his series-wound machine to keep the current constant.

The Clerc form, for alternating current machines, is similar in principle to the Edison described above, only that relay magnets are introduced to operate the two large powerful solenoids whose cores move the sliding contact. It is very large and complicated, and is burdened with many details. It is presumably only experimental.

In the Beau & Bertrand form the detector is a short but very wide magnet, having a large number of small armatures, of progressively increasing weight; these operate the resistance contacts and replace the usual sliding contact. It is large and awkward, but seems to work well.

Among other regulators for various purposes were the following: Lahmeyer regulates for the loss of potential in the leads by means of a small series wound dynamo on the same shaft with the other and connected in the main circuit. It is not apparent what the advantage is over the much more simple compound winding, which does precisely the same thing.

The Dujardin regulator is for putting resistance in the main circuit of a small number of incandescent lamps run from accumulators, to keep the potential at the lamp constant. The detector is an ordinary magnet with a very long contact arm, operating two contacts as usual; the two magnets moving a brush in one direction or the other over a series of resistance contacts, by means of a rachet wheel, pawls, and make and break contacts. He claims to be able to regulate within three-tenths of one per cent. The objection is to the number of contacts which require cleaning and attention.

Reference.—For a voltmeter for measuring the potential at the far end of the leads, without a return wire, see under "Voltmeters."

LIGHTNING ARRESTERS.

The few lightning arresters exhibited for electric-light lines were confined to the American exhibits; there was one in the French section, but it was an acknowledged copy of one of the former. These safety devices, so very common and necessary here, are conspicuous by their almost total absence in the foreign systems exhibited. This is to a great extent due to the fact that the lines are mostly underground, and are carefully kept free from grounds; also that high potential circuits are comparatively rare; also that such violent electric storms as we have are much less common on the continent. Another explanation of the absence of lightning protectors is that many systems there are not as completely equipped as they should be.

Thomson-Houston.—Among the most prominent lightning arresters were those exhibited by the Thomson-Houston Company. Those for continuous current circuits, though no longer new, are perhaps not well known.

The principle of all of them is that the lightning is led to earth by jumping across a small air space, and that the arc which is formed thereby, and which might be continued by the dynamo current, is blown out magnetically by means of a magnetic field produced by an an electro-magnet.

There are a number of different patterns, depending on whether they are for arc, for incandescent, for railroad, or alternating current circuits. In all of them the arc is formed between two metallic plates in the same plane, one connected to line and the other to earth; their adjacent edges, where the arc jumps over, are close together at one point, being separated only by an air space of one-sixteenth of an inch, and are far apart at the other; the magnetic field produced by the two poles of a U-shaped electro-magnet, which are situated on the two sides of this space, repels or blows this arc from the short toward the long air space, thus gradually increasing the length of the arc, which weakens it and finally extinguishes it.

In some (those for arc-light circuits) this electro-magnet is always in the main circuit, and is connected between the machine and the arrester, so that its self-induction helps to protect the machine. In others (for incandescent light and railroad circuits) the current for the electro-magnet is that of the arc itself, the magnet being connected between the ground plate and the ground; in this form the magnet circuit is shunted by a small air space between the two points, across which an excess of the lightning may pass.

For alternating currents the magnet, which is always in circuit, is ingeniously arranged; it is connected between the machine and the line and is wound bifilar, like a resistance coil (that is, with two equal windings in opposite direction), so as to have no self-induction and develop no magnetism under normal conditions. The "bight" or junction of these two opposing windings is connected to one of the plates of the arrester, the other being led to earth. When lightning strikes the line it passes through *only one* of these two windings, and hence through the plates to ground; this develops magnetism which blows out the arc. In addition to this there are points and plates separated by small air spaces, which shunt the coil and take the excess of the lightning current. To assist in blowing out the arc, a knife edge of slate is sometimes introduced in the air space between the plates, as if to cut the arc. In those for alternating currents the space in which the arc is formed is carefully insulated from all the rest of the apparatus by means of thick pieces of slate. The writer witnessed the experiment of short circuiting a 3,000-volt arc-light machine through one of the arc-light current arresters; the powerful arc formed was instantly blown out, accompanied by a loud report.

The Electrical Supply Company exhibited a lightning arrester, the principle of which was that the lightning passed between the usual plates, with saw teeth, to the ground, and in doing so it passed through a magnet which tripped a lever, which, by means of a simple drop mechanism, rapidly separated these two plates so as to extinguish the arc which might otherwise be continued by the line current.

A system which is said to be used in Switzerland, but was not exhibited, consists in introducing into the circuit a "choking" or self-induction coil between the machine and li [illegible] chine end of this coil is connected to a condenser, the other plate of which is grounded. The other end of the coil is connected to the usual saw-teeth lightning plates, one of which is grounded. The choking coil protects the dynamo by its self-induction. The fault of this apparatus is that it does not extinguish the arc should it be continued by the dynamo current through a second ground.

AUTOMATIC SAFETY CUT-OUTS AND FUSES.

Among the numerous exhibits in this class there was little of novelty, though some were of interest. The features desired in lead fuses, judging from the exhibits, appear to be to facilitate replacement, to make a burnt fuse render itself readily visible, and to guard against the scattering of the hot metal. There were exhibited a few electro-magnetic cut-outs, but they do not seem to meet with much favor, probably on account of their cost. There was only one high potential cut-out, that of Thomson.

Lead fuse cut-outs.—The fuse exhibited by Postel-Viney (French section) consists of a short glass tube with a copper cap at each end, the lead wire being in the interior, with its ends fused to the copper caps. The holder consists of two large screws, between the ends of which this tube is clamped axially at the caps. When a fuse is blown the tube becomes white inside, which enables it to be detected readily. The tube prevents the scattering of the metal.

The fuse on the Zippernowski transformer is similar to this one, only that it is attached to a wooden handle perpendicular to it, and the contacts are made in the form of spring clamps. The object is to enable a fuse to be replaced without having to touch the circuit.

In the Cockburn fuse exhibited by the Acme Electric Works (British section) the wire is long and horizontal, with a small weight attached to its middle point, which is intended to break the wire before it fuses.

In the Hedge fuse exhibited by the Globe Electrical Works (British section) there are two separate fuses in series, with a convenient short-circuiting switch by which either one may be short-circuited. Either one of them should always be short-circuited. When the one in use is blown the switch may be moved over to short-circuit its terminals, thus putting the other one in circuit. The blown fuse may then be replaced at leisure. The fuses themselves, as is well known, consist of a strip of tin foil between the two pieces of mica, which cover it completely.

Among the fuses in the Edison exhibit was one in which there were a number of independent fuses, with a switch enabling a new one to be switched into circuit very rapidly, giving time to replace the burnt one. These successive fuses may also, if desired, be made of increasing sizes for special purposes, the smallest one being normally in circuit. Their fuses for the municipal system (high potential) are made of a long lead wire wound spirally around a glass tube or slate block to prevent the formation of an arc.

Magnetic fuses.—Among these was one of Woodhouse & Rawson's, in which an electro-magnet in the line circuit attracts a weighted armature pivoted like an inverted pendulum. The moving of this armature ruptures the circuit by lifting out the bridge piece of two mercury cups. By the latter device sliding contacts at the movable armature are avoided. In another, for very large currents, exhibited by the Société Alsacienne de Constructions Mécaniques, the magnet trips a small light lever, which in turn trips a large heavy lever, which opens a snap switch by the action of a strong spring.

High potential safety device.—In the Thomson-Houston exhibit there was a switch consisting of a knob at the end of a flat spring which pressed it against a contact piece. A piece of paper pinched between the two insulates them from each other. The two parts are connected to the two mains or leads which are to be protected against a great increase of potential; when the potential becomes too high it pierces the paper, making contact between the two leads, thereby short-circuiting them. It is used on arc lamps in series to cut out the lamp should the circuit be open in the lamp. It is also used in the alternating current system, in which each of the secondary or house mains is connected to earth through such a cut-out. Should the potential of either one of them become too high, by a cross with the primaries, or by lightning, it will immediately be grounded, thus rendering it perfectly safe.

SWITCHES.

Among the necessarily very large number of switches exhibited there were but few that are of sufficient interest to be mentioned here. Small switches are as a rule so simple and so easy to design that there is little of interest to be described. For small currents it has become almost universal practice to use the so-called "snap switches"—that is, those which open with a snapping movement and have only two stable positions, either entirely open or entirely closed. Most others have gone almost entirely out of use. It is also becoming more general to use the double-contact switches, in which the circuit is broken twice. This may be due to the fact that it often simplifies the construction. Double-pole switches were rare. Porcelain and other similar substances* are coming into use more and more for small switches.

Switches for strong currents are much more difficult to design, requiring much more care in their designing than is often given them. The greater number of those exhibited were not well designed, so far as the contacts were concerned. The mere fact of having large surfaces and masses of copper does not necessarily mean that the contacts are good. They may keep cool, but this may be due to the large masses of good heat-conducting copper. Such switches may do their work, but they do not do credit to their designers. A switch must be exceedingly poor to fail completely. The contacts in many were examined carefully and were found to be very poor as compared to the size of the intended surfaces of contact. The bright parts of these surfaces are not necessarily indications of the size of the true contact, as they may be simply scratches from a mere line or point contact. Even some of the better companies had very poor types of switches. One of the large well known French companies even had a type of switch which could hardly have been designed worse: two rigid flat horizontal surfaces, one *laid* on top of the other. There was absolutely no sliding or friction, and no flexibility of the surfaces, a grain of dust would destroy the contact almost entirely, if not quite so, and the spark on opening completely destroys the contact surfaces.

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*See also "General supplies."

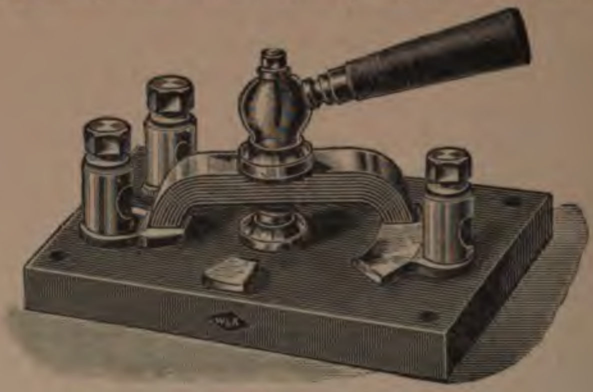

FIG. 8.—Two-way switch; by Woodhouse & Rawson.

The requirements of a good switch are, that the surfaces should be self-cleaning, that one of the two contact surfaces must be of a flexible yielding nature to adapt itself to the other, and that the spark on opening should take place at such parts of the switch which, if burnt, do not affect the contacts. A switch on the same principle as the contact of a commutator brush of a dynamo answers all these conditions. There were several such switches exhibited. When designed in this way, a small switch will carry a much larger current.

Switches of the class just described were exhibited by Woodhouse & Rawson, Crompton, Société Alsacienne de Construction Mécanique, Iliyne-Berline, Hedge, and Augé. Some of those of Woodhouse & Rawson are shown in the three adjoining cuts; the first, Fig. 8, is a two-way switch, the second, Fig. 9, and third, Fig. 10, are snap switches. The movable contact in all of these is made of a large number of fine strips of spring copper, each of which adjusts itself to touch along the whole length of its edge; the total surface of contact is then equal to the total cross section of the arm. At the ends these strips should be slightly separated from each other so as to allow for a slight play to adjust themselves.

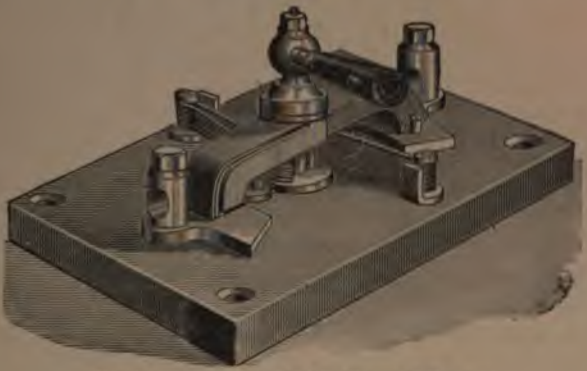

FIG. 9.—Snap switch; by Woodhouse & Rawson.

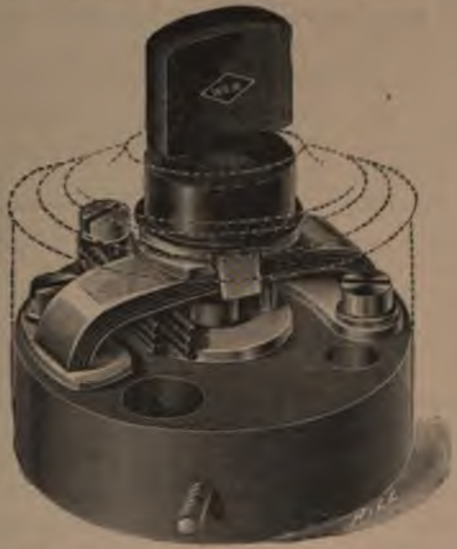

FIG. 10.—Snap switch; by Woodhouse & Rawson.

Almost all the others are similar in principle but differ in construction. In one of them (Crompton) there is, in addition, a small replaceable spring fastened on one side of the contact springs, which takes the spark and thereby prevents the others from being burnt.

In those of the Alsacienne Company the upper foil was too stiff to adjust itself, many of the springs touching in a point only instead of a line.

In those of Iliyne-Berline the foils were bent, somewhat like the letter S, and were in planes parallel to the axis instead of perpendicular, as in the others, rubbing on the inside of a cylindrical surface. This has the advantage that the springs will not wear grooves in the solid surface; it has the disadvantages that the snapping of the springs on opening make a great noise, and that it can be turned one way only.

In the Hedge form both surfaces are flat, but the movable one is connected with the lever by a flexible connection, thereby allowing it to adjust itself to the other surface. An interesting and ingenious feature of all the switches, cut-outs, etc., of Hedge's is that all screws which may have to be used in making the connections have a high projecting head with a deep, wide cut; the object of this is to enable any ordinary coin to be used in place of a screw-driver; a screw-driver is not always at hand, but a coin generally is.

In many of the large, as also in small switches of various types, it was noticed that the hinge or pivot of the movable lever is rarely used as one of the contacts; the lever is preferably made so as to break two contacts, in which case the hinge is not in the circuit.

The Oerlikon circuit breaker is intended for opening circuits of several hundred ampères and several hundred volts, such as those used in their transmission of power. For such currents an ordinary switch will evidently not answer. In this cut-out there are two contacts in multiple arc; one is a good metallic contact made by a large carbon rod forced in between two spring sockets, and connected by a flexible lead. To open the circuit, the metallic contact is first opened by lifting the carbon out of its seat; this throws all the current through the carbon contact, which is then broken by pulling it out of its socket. All of the spark, which is very large, is therefore taken by the carbon and not by the switch proper.

COUPLINGS FOR WIRES.

There were three different couplings for line wires exhibited, one French and two American.

The former, exhibited by Lapointe, is for fine wires only. It consists of two copper tubes, one with a male screw thread on the end and the other with a female screw. The ends to be spliced are each threaded through both tubes and passed through a lateral hole at the end of the farther tube. The two tubes are then screwed together, which twists the wire together. It forms a strong joint and is easily made, but the contact is not necessarily much better, if as good, as the usual twisted splice.

The McIntyre coupling (United States section) is well known here. It consists of two tubes soldered together so as to have a cross section like a figure 8. The ends of the wires are passed, one into each of these tubes and from alternate ends, the whole being then twisted;

the flattening of the tubes caused thereby makes contact with the surface of the wire, while the twist gives the splice mechanical strength. The objection is that the tubes, which are moderately long, especially for thick wires, must fit the wire closely, and it is not always easy or simple, especially on top of a pole, to straighten such long ends of the wire so that they will go in. For thick wires, as for arc-light circuits, it requires two special tools and two men to twist the coupling.

The Hering coupling exhibited by the Electrical Supply Company (United States section) and known as the "vise grip" coupling, consists of two short split tubes which fit the wire moderately closely, and which are connected together parallel to each other by two flat pieces; after the wires are inserted these flat pieces are bent, by a blow of the hammer, so as to bring the tubes together; the construction is such that this causes the tubes to close on to the wire like the grip of the hand, with a very great force, which is sufficient even to stretch the copper tubes. The contact is therefore around the whole surface of the wire, and is therefore very large and good. The time required is very much less than that for an ordinary twist coupling. The length of wire used is less than one-half of that required for the usual splice.

BINDING POSTS.

Among the binding posts exhibited were several of interest. The one exhibited by Woodhouse & Rawson, shown in Fig. 11, consists of a slotted bolt and nut; the wire to be clamped is placed through the slot; it has a number of obvious advantages. A very good spring clamp binding post exhibited by Camus (French section) is shown in Fig. 12. The cap is capable of being lifted up slightly, being held down by the spring; the wire is placed under its edge or through the hole in the pin, the spring cap holding it there securely. Its use is limited to temporary connections such as with instruments, for instance, for which purpose it is very convenient.

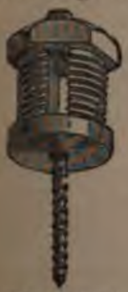
FIG. 11.—Binding post; by Woodhouse & Rawson.

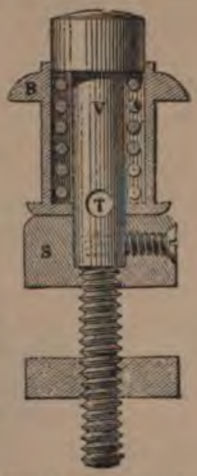

FIG. 12.—Binding post; by Camus, France.

The following simple and very good binding post was quite common, particularly on French machinery. It is for connecting stranded cables for strong currents to dynamos, switch boards, etc. It consists of a short semicylindrical block, which rests with its curved surface in a corresponding grooved block, which forms the base; two bolts, passing transversely through it, enable it to be clamped down into this groove. The stranded end of the cable, slightly flattened, is passed between this semicylindrical piece and its grooved seat, and is then secured there by tightening the bolts. By virtue of the slight bending and spreading out of the strands, all, or almost all, of the strands are brought into contact with each other or with the clamp. An illustration of it may be found in the recording ampèremeter (Fig. 59), under "Instruments." It replaces the solid eye piece which is generally used with stranded cables, but which requires to be soldered to the cable, and is therefore not so convenient, although neater.

MISCELLANEOUS ACCESSORIES.

Choking coil.—In the Thomson exhibit (United States section) was shown an induction or "choking" coil, by which the amount of apparent self-induction could readily be varied at pleasure. It is for use with alternating currents just as an adjustable resistance is used with continuous currents, and like these it absorbs energy, and its use is therefore limited in practice. Its chief advantage is its convenience and the absence of all contacts. It may be described as resembling a Gramme ring, with a single coil, covering about one-third of the ring; this is the induction coil. Another third of the ring is encircled by a single short-circuited coil, made of solid thick pieces of copper; this fits very loosely, and is capable of being moved about the axis of the ring as a center, by means of a handle, so that it can be moved over any portion of the ring or the induction coil; lastly, the open space in the ring is filled with round iron disks. When the two coils are on opposite sides there is practically no induction in the solid copper coil, as it is magnetically shielded by the iron disks. As it is moved over the other, currents will be induced in it, which will be a maximum when it completely covers the induction coil, in which position the apparatus is a true transformer, with a short-circuited secondary. This variable induction in the secondary will generate a variable counter-electromotive force in the

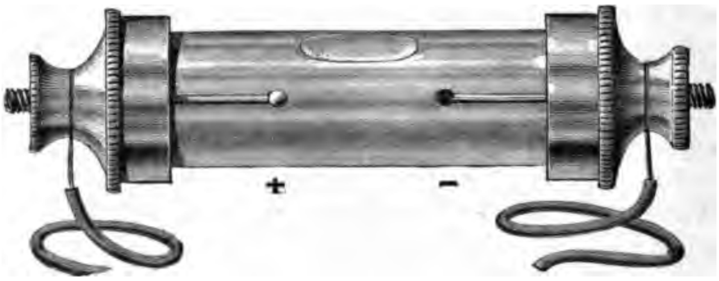

FIG. 13.—Pole indicator; by Woodhouse & Rawson.

primary, by which any required apparent self-induction can be obtained.

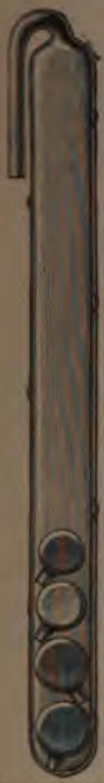

Fig. 14.—Hicks' hydrometer, for accumulators.

Pole indicator.—Woodhouse & Rawson, Danzer, and others exhibited a pole indicator, by which the polarity of a circuit can readily be found. It consists, as shown in Fig. 13, of a glass tube containing a liquid and two platinum terminals. If these are connected to the two poles of a dynamo or a circuit, the one connected to the negative pole will turn a pink color. Its resistance is given as 30,000 ohms. It can, therefore, be used for high potential circuits. It is said never to require a change of the liquid.

Accumulator hydrometer.—The Hicks hydrometer, shown in the adjoining cut (Fig. 14), exhibited by Woodhouse & Rawson, is to replace the usual hydrometers for accumulators. It consists of a flat glass tube, perforated with small holes, and containing four little glass globules of different colors, each of which will rise or fall for a distinct specific gravity. It is arranged to hang over the edge of the cell, by means of the hook at the top.

Wire straightener.—The adjoining cut (Fig. 15) shows a very convenient and probably very effective wire straightener, for use in winding magnets, especially for large, thick wires. It was exhibited by Woodhouse & Rawson. The wire passes through axially and on alternate sides of the rollers, which are adjustable. Besides the straightening effect of the rollers themselves, the whole frame is made to revolve, having therefore the effect of many rollers in different planes.

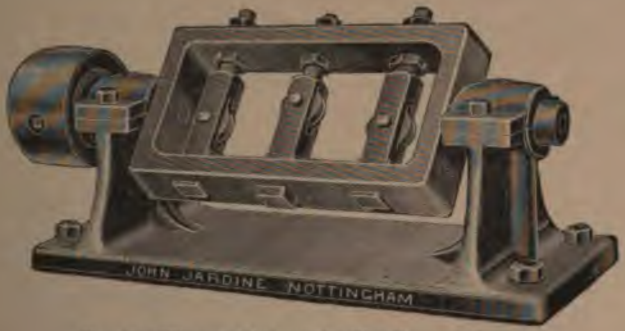

Fig. 15.—Wire straightener; by Woodhouse & Rawson.

Driving-gear for dynamos.—See "Dynamo accessories."

MISCELLANEOUS APPLICATIONS OF ELECTRICAL ENERGY.

Under this heading will be mentioned only those applications in which the more powerful currents are required, as distinguished from the many applications of a lighter character which belong more properly to the same class as electric bells, annunciation, gas ignition, etc., which see for other miscellaneous applications. Electro-metallurgical applications of electricity are not included in this report, as they belong more properly to the department of Mining and Metallurgy.

ELECTRIC WELDING.

There were two exhibits of electric welding, one, the Thomson process, by directing heating, and the other the Bernados process, sometimes called the Russian process, by means of the electric arc.

Thomson's process.—The Thomson process was invented within the last few years by Prof. Elihu Thomson of Boston. The exhibit of this process in operation (United States section) was exceedingly interesting and attracted probably more attention among both technical persons and the general public than any one other electrical exhibit.

Electric welding is one of the very few recent developments of an important character in an entirely new direction. The exhibit was very complete, including a number of different machines for different purposes. They were designed in all their details in as complete and practical form as possible, a characteristic feature of many of the American exhibits.

The principle is, that the two ends to be welded are brought together, and a powerful current passed through the contact at their junction; owing to the resistance of this imperfect contact, the metal is heated very rapidly at this point and in its immediate vicinity until a welding heat is reached, when the pieces may be pressed together slightly. The welds are necessarily always "butt" welds. The cooling action of the clamps, and the fact that the high resistance due to the high temperature keeps generating more heat there, both tend to keep the heat confined to the immediate vicinity of the joint.

The machines, in general, consist of two clamps of copper for holding the pieces and for conducting the current to and from them; one of them may be moved parallel to itself by a lever or other device. These clamps with the pieces to be welded form part of a large transformer, of which they are a part of the secondary coil which has only a single winding, consisting of a large bar of copper; the contact at the weld forms a short circuit to this coil.

In all of the machines the current was started, broken, or regulated by switches and resistances in the primary circuit of the transformer, or in the exciting current of the dynamo, thereby avoiding the use of all switches, etc., in the low-resistance circuit of the welding current.

There were four machines exhibited; the large one, for iron bars from 1 to 2 inches in diameter, consisted essentially of a large transformer, a separate alternating-current dynamo, and an exciter for that dynamo, the exciting current being controlled and regulated by the operator at the welding machine.

The second one, for ½ to 1 inch iron bars, consisted merely of a transformer, and is intended to be used when the current can be taken from the general mains of a system of alternate-current distribution, in place of using a dynamo and steam power.

The third one, called the direct welder, for ⅛ to ½ inch iron bars, is for use with power direct, and consists essentially of a small dynamo with an armature similar to the old Siemens H armatures, having two windings, a very coarse one in which the alternating current was not redressed, and which was connected directly to the clamps, and the other a small one in which the current was redressed and formed the exciting current for the field. The dynamo was situated immediately under the working table, thereby reducing the length of the leads for the welding current as much as possible.

The fourth was a small automatic welder for copper wire from Nos. 6 to 10 B. & S. It was arranged to automatically open the circuit when the weld was finished, that is, as soon as the softening of the metal permitted the clamp to move forward a slight distance. It was arranged with a small transformer, and was especially adapted for small chains and similar work. The current was regulated by a "choking" coil (see "Accessories"). Many of the details that can not be included in this short description are very ingenious and are arranged very practically to make the operation as simple and rapid as possible.

Among the chief advantages claimed are the great simplicity and rapidity of the operation, the perfect nature and reliability of the weld, the clean form of the weld requiring little dressing afterwards, its application to short pieces and in general where other methods fail; also its use for welding metals that could not be welded by the ordinary methods, replacing therefore the usual soldering.

The exhibit included welds of the following metals: Gold, platinum, silver, copper, aluminium, bismuth, cobalt, nickel, antimony, zinc, tin, lead, wrought iron, cast iron, magnesium, German silver, brass, and steel; also welds of nickel with iron, iron with steel, gold with silver, platinum with gold, brass with copper, iron with brass, German silver with iron, brass with German silver, German silver with copper, also lead with other metals.

Applications.—Among the uses to which it is already applied in practice are the following: In chain welding, in steel tube welding, in wire-drawing establishments, for joining hauling cables, for carriage fittings of all kinds, for pipe welding up to 5 inches in diameter, in making homogeneous tubes for ice machines, in pipe bending, for making springs, for joining bands for bales and boxes, for splicing band saws, for making carpenter's and machinist's try squares, etc. It is also used for raising a collar or shoulder on a bar of iron by heating it in the welder and, while hot, compressing the bar lengthwise to enlarge the diameter.

A machine is also being constructed for riveting, in which the two clamps are replaced by two heavy pieces of copper with conical holes, facing each other; the rivet becomes heated at its ends where it touches these two holes, the large size of these metallic pieces preventing them from becoming so hot as to become welded to the rivets.

Power consumed.—The following table gives some data regarding the power required for the welds, also some deductions made therefrom by the writer, which may be of interest. The welds were made with wrought-iron bars of different diameters; the energy was that delivered to the primary coil of the transformer; the current and potential are those at the weld; the former was measured at the weld and the latter was calculated from the energy in the primary coil, allowing about 90 per cent efficiency for the conversion.

Diameter of wrought iron bar.	Kilowatts in the primary.	Time.	Units of heat consumed.	Potential at the weld.	Current through the weld.
Inches.		*Secs.*		*Volts.*	*Ampères.*
2	61.6	50	2,900	2.06	27,000
2	52.8	58	2,900	1.98	24,000
2	31.2	144	4,300	1.74	16,000
1	13.0	43	530	1.51	7,750
1	12.4	44	520	1.74	6,400
¾	7.8	33	250	1.46	4,800
¾	7.5	35	250	1.52	4,500
½	4.1	18	70	1.16	3,200
½	3.5	21	70	1.12	2,800

Strength of the weld.—In the opinion of the writer too much stress is often put on the fact that there is often a loss of tensile strength at the weld, as the most important advantages of electric welding are thereby overlooked. The chief advantages of electric welding are given above, and the strength of the weld is in most of cases of small importance as compared with the other advantages. At the same time official tests show that the tensile strength per square inch is in many cases not reduced very much, and that what loss there is is due in many cases to the fact that the metal has been heated, and not to imperfections in the weld; without heating, a weld can not be made.

A proper comparison, therefore, would be between a weld and a similar bar which has been heated. Such a comparison can be reduced from the official tests made at the Watertown Arsenal, which are included in a paper on electric welding by Woodbury in the transaction of the American Society of Mechanical Engineers, Vol. x, No. CCCXV. By comparing proper samples in these tables it will be seen that wrought iron, copper, and brass bars have practically the same tensile strength per square inch before and after the weld, the bars (except the copper) which were not welded having been heated.

The weld can evidently be made stronger than the rest of the bar if it is slightly enlarged at the weld, which in many cases, as in chains, for instance, is not an objection. Prof. Dolbear states: "I had a number of bars welded by an expert blacksmith and a number of similar ones by the electrical process for comparison, with the results that the electrically welded bars were much stronger than those welded by the ordinary process. The bars were of various sizes, up to an inch and a half for iron and three-fourths of an inch octagon steel."

Bernados process.—The Bernados process of welding by the electric arc was exhibited by the Société Anonyme pour le Travail des Métaux (French section). The current was obtained from a large battery of accumulators, of 75 volts and 200 ampères. The carbon rod held in the hand is connected to the positive pole, and an iron table on which the welding takes place is the negative pole. The carbon is about half an inch in diameter, and is provided with a suitable handle, a flexible lead, and a heat shield to protect the hand; the operator uses a blue-glass screen. The arc is very long, and the process occupies considerably longer time than the Thomson process. The writer found that it took from 3 to 5 minutes to make a weld of a piece of iron ¼ by 1¼ inch. The joint must be hammered, as in a smith's weld. As the metal is burnt and brittle where it is welded, the process is not a success. Its only commercial application at present is to weld nickel tubes to iron ones, for the tubes used in glass-blowing.

APPLICATIONS OF POWER.

Bon & Lustrement (French section) operated one of the two traveling cranes in Machinery Hall by means of an electric motor. The single motor and generator were both series machines; the former turned always in one direction. The three operations of moving the crane bodily on its track, of moving the lifting mechanism on the crane, and of raising the weight, were all done by means of conical and cylindrical friction wheels; the reversing and changing of speed were all done mechanically, the motor being run continually at a constant speed and in the same direction. The mechanism required to do this was therefore much more complicated than if it had been done electrically, as with the motors on an electric railway. The current was taken from two bare wires immediately alongside of the track.

Megy, Echeverria & Bazan (French section, silver medal) operated the other traveling crane. It was quite similar to the first only that a different kind of friction clutch was used.

Chrétien (French section, silver medal) exhibited an elevator driven by electric motors. The electrical system was, as in most of these power transmissions exhibited, a simple series system with series wound motors. There were two motors in series driving the rope drums by means of worm wheels. The leads pass through the elevator shaft as four bare strips against which slide the brushes of the car, which contains the switch and the resistance for starting. One of these strips is in some places broken into a number of short pieces which are connected by resistances which are put into circuit automatically by the car as it passes this point. These are located just before the stopping places, so as to stop the motor gradually. The motors turn in two directions and have a mechanical device for shifting the brushes on reversing. There is a weighted brake on each motor shaft held off by an electro-magnet in the main circuit. The brake is therefore automatically applied as soon as the current is stopped, intentionally or accidentally.

Sperry (United States section) exhibited a horizontal mining drill operated by an electro-motor. The drill moves axially and strikes with a blow. The essential feature is that the motor merely pulls the drill back against the action of a strong spring and then releases it, thereby allowing it to strike with a sharp blow. The blows are in very rapid succession. The motor is an ordinary rotary one, the reciprocating motion being produced by gearing and a pawl. The whole is balanced on two low wheels. For an illustration see Electrical World, June 15, 1889.

Hillairet (French section) exhibited a mining drill, of the rotary type, which was connected directly to the shaft of the motor as a continuation of it, the motor being supported by a toggle joint in a tripod.

Renard (French section) exhibited a motor as applied to propelling the great military balloon "La France." It was intended to be run by batteries. The arrangement exhibited was an experimental apparatus to measure the turning force and the axial thrust of the fan-shaped air propeller. The whole mechanism was supported so that these forces could be balanced by weights on lever arms and thereby measured. For a description of the primary battery, see under that heading.

Trouvé exhibited, among many other applications, a small boat (not in operation) driven by an electric motor from bichromate batteries. The peculiar feature is that the motor was secured to the top of the rudder and was geared directly to the propeller by chain gearing, the propeller being also in the rudder itself. It is not clear what special advantages this is intended to have, except in turning. With a motor having two armatures 6 inches long, he obtained a speed of 6 knots an hour. He experimented with electrical navigation on the Seine as early as 1881. No figures of importance could be obtained from the attendant of the exhibit, but as a primary battery of the well-known forms was used, the quantity of power carried could not be very great, and would necessarily be very expensive on account of the materials consumed. For some additional remarks see "Primary Batteries."

Deprez (French section) exhibited a number of applications of electrical power. One was in the form of a drop hammer in which a coil around the hammer shaft was intended to lift the hammer by the magnetic action of drawing it into the coil. It was not in operation. A crane attached to the hammer to hold the material was also operated electrically. All switches were controlled by one operator at the hammer. Another application was a sort of revolving capstan having a motor underneath it to turn it. It is used by some of the French railroad companies for drawing cars over short distances in drilling a train, where horses were formerly employed.

Guyenet (French section) exhibited a traveling crane and a windlass, designed for use chiefly in storehouses. The electric motor was pivoted so as to be movable slightly parallel to its shaft. One end of the shaft was a small cylindrical friction pulley which drove a large double-rimmed pulley in one direction or the other according as it was pressed on to the inside surface of the annular rim or on the outside surface of the other rim; this was effected by moving the whole dynamo by a conveniently arranged lever. The whole was very practically arranged, but leaves little to be described from an electrical point of view.

Sautter, Lemonnier & Co. exhibited a complete outfit of an engine, dynamo, and projector, which is used on the vessels passing through the Suez Canal. The engine and dynamo are together on the same base plate, and can be installed on a steamer in 40 minutes. A local company rents these outfits at £10 for one passage. It is stated that 72 per cent of the vessels pass at night, with the electric light, in 18 hours. The authorities are said to require every vessel that passes at night, to carry an electric light or projector enabling them to see a distance ahead of at least 1,200 meters (about 4,000 feet).

MAGNETIC SEPARATORS OR SORTERS.

The object of these machines is to separate particles of iron or other magnetic matter from any non-magnetic matter with which they are mixed. They are used largely in the arts, chiefly for the following purposes: In mining and metallurgy for the separation of the mineral magnetite or magnetic iron ore from its accompanying minerals; in machine shops and foundries, to extract the iron from filings, turnings, and chippings (an operation which is often done by hand, but which is very injurious to the health of the workman on account of the fine copper and brass dust); in flour mills to extract fragments of iron from the grain; in the manufacture of white zinc oxide, to extract magnetic impurities; in numerous industries, to extract pieces of iron from crude materials to which they have been fraudulently added to increase the weight.

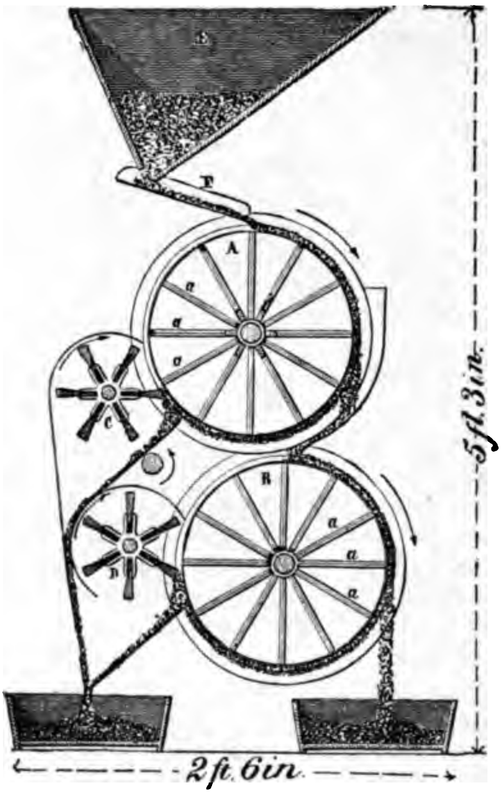

FIG. 16.—Magnetic separating machine; by Vavin, France.

The general principle of all these machines is that the material in the form of sand, powder, or small particles, is made to pass over or near powerful magnets which attract the iron particles or the magnetic iron ore, and allow all the other materials to pass by, thus affording a very good, simple, and reliable means of effecting a separation.

There were three of these machines exhibited, one each from France, the United States, and Belgium, differing only in the manner in which this principle was applied.

Charles Vavin (French section, bronze medal) exhibited the machine shown in the adjoining cut, Fig. 16. The material falls on the two drums, as shown. Each drum is made of four wheels; the spokes, *a a*, of these wheels are permanent magnets, having their like poles at the circumference, and there connected in common to an iron ring, which, therefore, forms one of the magnetic poles on the surface of the drum. The four wheels, making one drum, are alternately of north and of south polarity, forming, therefore, strong magnetic fields all over the surface of the drums. The material falls, as shown, over these drums revolving at the rate of thirty-two revolutions per minute; that which is magnetic attaches itself to these drums and is brushed off by the revolving brushes C and D. The object of two drums is to repeat the operation to make the separation more thorough. This is probably necessitated by the fact that permanent magnets are at their best not very strong.

Its working capacity is said to be 660 pounds per hour; it requires one-sixteenth of a horse power, and can be turned by hand. There are over five hundred of them in use. It has the great advantage over the others in that no battery or dynamo is required to generate the magnetism, as the magnets are permanent. It appears to be used chiefly in machine shops.

The Edison sorter consists simply of a hopper and a huge electromagnet. The material falls continuously, in form of a sheet, from a long, narrow slot in the bottom of the hopper, and in its fall it passes by and near to the pole of the large magnet, but does not touch it; that material which is not magnetic falls perfectly vertically, while that which is magnetic is attracted toward the magnet and is thereby deflected from its vertical course, falling on the other side of a partition which separates it from that which falls vertically. The advantages are that the process is very rapid and requires no power except the current for the magnet. The disadvantages are that a battery or a dynamo is required and that only a certain class of material, such as sand, can be made to fall in front of the magnet in the form of a thin sheet. Probably for this reason it appears to be used chiefly in mining, for separating the magnetic iron ore from its accompanying minerals. It is claimed that black sand, found in so many places, as well as other iron ores which are too poor to be worked by other methods, can be worked to great advantage by this machine.

In Jasper's sorter, exhibited by Eschger, Ghesquière & Co. (Belgian section), the object seems to be to obtain an exceedingly intense magnetic force, and it appears to be used chiefly in the manufacture of zinc and zinc oxide. It consists of two iron horizontal rollers, side by side and almost touching each other, somewhat resembling crushing rollers. The ends of these rollers, next to their bearings, pass through fixed coils of wire through which a current is passed, which magnetizes them so that the one roller is a north pole at the exposed portion between the coils, and the other is a south pole. The narrow space between them is, therefore, an exceedingly intense field. The material is made to pass between these rollers at this place, the rollers turning in the opposite direction to that in which they would turn if they were intended to crush the material. The magnetic particles, therefore, attach themselves to these rollers, are carried out over the rollers and scraped off by means of scrapers, while the non-magnetic material falls through the space between the rollers. As the bearings must necessarily be magnetized by this disposition of parts, there will doubtless be considerable friction produced. Its capacity is stated to be 4,400 pounds per hour, and it requires 2 horse power.

ILLUMINATED FOUNTAINS.

The most effective decorative display of electric lighting and its advantage over other lighting was shown in the very attractive illuminated fountains on the exhibition grounds. They were not only the chief and very effective attraction in the evenings for the general public, but were of considerable interest from a technical point of view.

The finest part of the fountain was the same that was used in the Glasgow exhibition of 1888, and known as the Galloway fountain (English section, gold medal). As it has been described in the technical journals it is not necessary to give a detailed description here.

The principle of the illumination is that a powerful beam of light is passed vertically upward through a hole in the top of a tunnel under the fountain, the hole being covered by a glass plate above the water level. Above this plate the jets are arranged so that the water passes up through this beam and remains entirely within the vertical conical space illuminated by the beam; it thereby becomes highly illuminated, while the beam of light itself is quite invisible, the glass plate and jets being hidden from view by some decorations around them.

The effect is exceedingly striking and beautiful. Glass plates of different colors were moved into the beam below the jets, thereby coloring the light: all these, as also the valves for playing the jets, were under the complete control of the operator and were controlled with the greatest facility; the lights are powerful 60-ampere arc lamps with reflectors or lenses or both, to give the rays of the beam the proper direction. There were thirty-three of them, which, together with fourteen others, required 300 horse power. They were all hand regulators.

Another system was also tried, but it was not a success; it was intended to be an application of the well-known physical experiment of internal illumination of a clear jet of water issuing horizontally. Although the jet was illuminated it was so only for a short distance, when the light was dispersed. The same was tried at the Philadelphia Electrical Exhibition in 1884, but was abandoned as unsuccessful. An illustrated description of this Paris fountain will be found in the Electrical World, June 15, 1889.

II.—TELEGRAPHY AND TELEPHONY.

TELEGRAPHY.

GENERAL.

With the exception of a few exhibits, there was comparatively little of special interest as a novelty or an important departure in a new direction. The exhibits showed little more than the natural progress of an already well studied and well developed industry. The progress shown was almost entirely in details and in the gradual development of existing systems and apparatus, rather than in the introduction of entirely new ones. Telegraphy has already reached such a high degree of perfection and development that further progress is necessarily slow.

Among the new departures from the usual systems may be mentioned the telautograph of Gray, for reproducing the movements of a pencil; the steno-telegraph of Cassagnes, which is based on stenography; the train telegraphy of Edison, based on static induction, and an attempt at telephonography by Lambrigot. If some of these should develop into important systems they would be more likely to create new fields for telegraphy than to replace the present systems.

Among the more important recent developments of existing systems may be mentioned the Wheatstone automatic system, the duplexing and quadruplexing of the more complicated systems, the Baudot multiplex, and some harmonic systems. Of these, probably the most important is the Wheatstone automatic, which has now been increased to six hundred words per minute, which is from three to four times as fast as one can speak or transmit through a telephone. It is duplexed up to four hundred words, and is therefore a formidable opponent to the multiplex systems.

The telephone, as a sounder, is coming into use more and more in numerous systems.

In the city of Paris itself messages are sent almost entirely by the pneumatic-tube system, in preference to electrical transmission. The former presents many advantages besides being very cheap and

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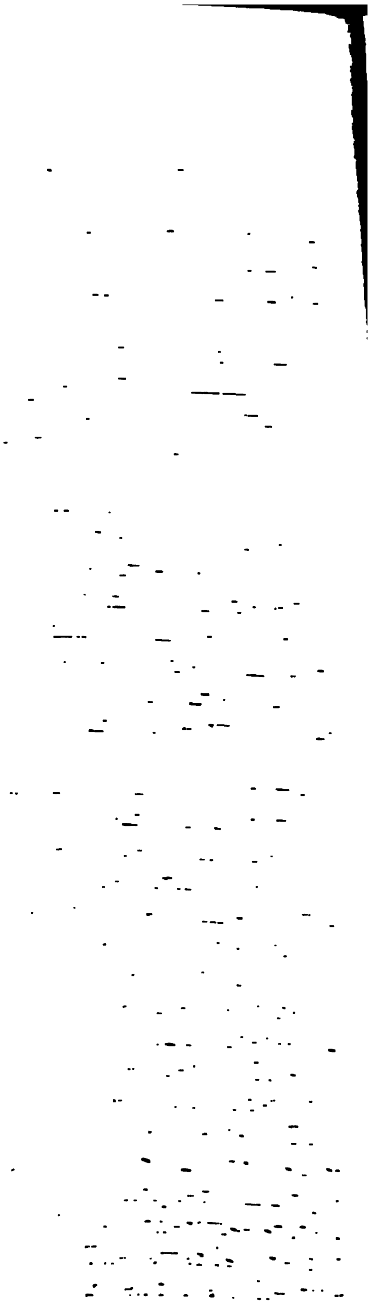


[illegible] SYSTEMS.

[illegible] Electric Company (United States se- [illegible] one of the first dispatches sent in 1844. [illegible] paper one inch and a half wide, with the Morse [illegible] the paper. The [illegible] exhibited the lead type [illegible] and Morse automatic transmitters. The Hughes apparatus, so largely used in [illegible] since 1878, when the mechanical controlling apparatus was being substituted for the electrical. In some of the larger stations power is being introduced, in the form of gas, steam, water, or other motors for winding up the weights. Several exhibits were shown for facilitating this winding up of the power weight. A modification introduced on some instruments is a double type wheel printing a duplicate message for various purposes, such as press dispatches, for instance.

Wunschendorff exhibited a cam attachment to the type wheel, for automatically moving a contact spring for making contact with a discharging battery.

Estienne system.—In the system devised by Estienne (French section, honorable mention), the usual horizontal dots and dashes are replaced by a short and long *vertical* line, respectively, printed on the tape by positive and negative currents. The advantages claimed are that the two signs have the same duration and are therefore independent of retardation, which therefore simplifies the automatic transmission; that the reading is simpler, the tape shorter, and the chances for error less. It is also more rapid, and therefore increases the capacity of a line. The key is a double one, sending positive or negative currents to line, in place of dots and dashes, respectively. The receiver is an ink writer, having a polarized armature which prints a short or a long mark according to the direction of the current. They are used in Germany and have been tried in France on underground lines and sea cables, as also from Paris to Berlin. But it was found that they were not altogether satisfactory, as they get out of order easily and require much regulation. The speed is only slightly greater than that of the Morse and considerably inferior to that of the Hughes.

Herodote modification.—Herodote modified the above system by making a small addition only to the usual Morse printer at present in use in France. He added simply another magnet and pen, but with a polarized armature, which printed vertically above the other, both of them printing vertical lines instead of horizontal. For a positive current only one of them printed, while for a negative current both printed simultaneously, producing therefore a short and a long vertical sign similar to those in the Estienne. Neither of these systems is, however, new, as an Englishman named Herring suggested a similar system of vertical signs with reversed currents as early as 1871.

Permanent charge system.—An ingenious system of Bouchard (French section, honorable mention) enables the number of cells used to be reduced to one-half, in a certain sense, by using half the number of cells at one station and half at the other. An equal number of cells is at each end of the line, with like poles to line. The sending key has an attachment to it which, when the key is depressed, reverses the poles of the sending battery, thus putting the two in series for the moment, and thereby sending a current to line. Though ingenious, it can not well be adapted to lines which serve several different stations, which is often the case.

Steno-telegraphy.—An interesting departure from the usual systems of telegraphy was exhibited by G. A. Cassagnes (French section, silver medal). The principle of this system is that instead of telegraphing *letters* as usual, he telegraphs characters representing the *sounds* composing the words. The advantages are, therefore, similar to the advantages of stenography over the ordinary writing. A message can thereby be sent as rapidly as it can be spoken. As

STENO-TELEGRAPHIC DISPATCH.

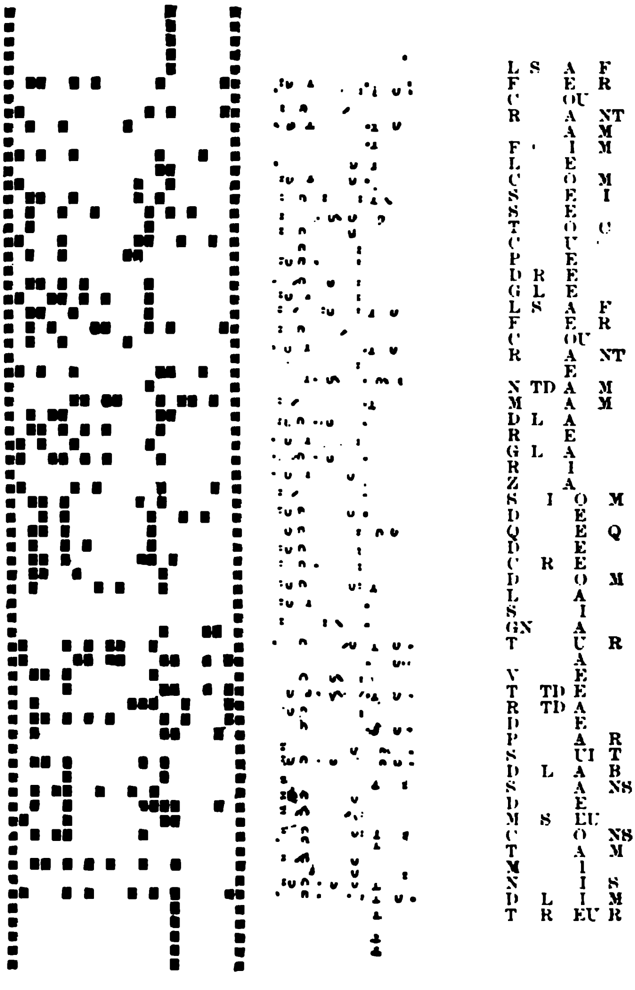


FIG. 17.—Perforated band, for transmitting.

FIG. 18.—The dispatch as received.

FIG. 19.—Translation of the characters into letters.

it takes much less time to transmit the characters representing the sounds, than it does the letters, the carrying capacity of the lines is greatly increased.

The system is briefly as follows: A band is perforated with holes representing the sounds; this is passed through the mechanical transmitter, which sends corresponding signals to line; on the receiver these signals are recorded as printed signs, which are then readily translated into the usual letters. Figures, 17, 18, and 19, will show the different stages of a message. A short paragraph from a daily paper was selected at random by the writer and was read to the operator about as fast as one would talk; the band was punched, transmitted, and retranslated, each about at the same rate. The paragraph which is given below contains 40 words and was read in about fifteen seconds. The first band, Fig. 17, is the one punched by the stenographer; the one next to it, Fig. 18, shows the corresponding characters as received, and the third one, Fig. 19, shows the message as translated from the second, by an operator on another machine. The paragraph is as follows:

LES AFFAIRES COURANTES.

Enfin le conseil s'est occupé de régler les affaires courantes et notamment de la régularisation de quelques décrets dont la signature avait été retardée par suite de l'absence de M. Constans, ministre de l'intérieur.

The first instrument, the perforater, is based on the principles of the Michela's stenographic machine, and consists of twenty keys arranged like those of a piano, which work twenty punches. These are worked with both hands by the stenographer, different combinations of the keys representing the different sounds. It is claimed that with this machine a skilled operator can stenograph 200 words per minute in any language.

The band thus punched is shown, half size, in Fig. 17. This is then passed through the mechanical transmitter which sends alternate positive and negative impulses to line corresponding to the perforations. These are sent over a single line by means of any convenient multiplex system, the one employed being the synchronizing system of La Cour, known as the phonic wheel, which is too well known to require description here. By means of it the twenty different impulses are received by as many corresponding relays at the receiving end, which operate the printer.

Every turn of the synchronizing wheel represents one line in the message illustrated above. The message thus received and shown in Fig. 18 is then translated into the usual written language. Fig. 19 is a literal translation of the characters in Fig. 18. It is claimed that 15 days suffice to learn to read the tape fluently and about 6 months to stenograph at the rate of 150 to 200 words per minute.

Besides the speed of transmission over the wire itself, the additional advantage claimed is that of the speed of preparing the message for transmission. It is in this feature that it excels the Wheatstone automatic system. It is claimed, for instance, that the first sentences of a speech begun in Paris at 2 p. m. could be composed in a printing office at Marseilles (about 540 miles distant) at 2.10 p. m., the stenographer always following the orator. Such a speech could be printed and distributed simultaneously in Paris and Marseilles. Experiments have been made on the French lines, in one of which, made in October, 1886, the following results were obtained: Up to 220 miles, 24,000 words per hour; up to 400 miles, 17,000 words; up to 569 miles, 12,000 words. The chief use would appear to be for press dispatches. As to actual speed of transmission over an average line it does not appear to exceed that of the Wheatstone automatic system, which is in use largely in England at the rate of 300 words per minute, and which has the additional advantage that the words are spelled as usual, thereby avoiding many possible errors.

Embossing and translating system.—In the Edison embossing and translating system the record of the transmitter is made in the form of a spiral groove on a circular revolving disk, by indentations in these disks. These may then be put directly into a transmitter for automatically repeating the message onto another line.

Train telegraphy.—The Edison-Smith system of telegraphing to and from moving trains consists essentially of a key, a phonetic receiver (telephone), and a high tension alternating current as produced by an induction coil. The train apparatus is connected between the metallic insulated roof of a car and the ground, through the wheels. The action depends on the static induction between the roof of the car and the fixed line wire on the poles alongside; and as the action is that of alternating condenser charges, it is independent of the regular Morse transmission on the same line. It is said to have been operated through an air space of 580 feet between the car and the line wire. Edison suggests this system for the intercommunication between ships at sea.

Telephonograph.—Lambrigot (French section, bronze medal) exhibited an apparatus called a telephonograph, which is a combination of a telephone and a phonograph, by means of which a message may be sent over a line as a telephonic message and recorded at the receiving end on a phonograph. This phonographic record on a strip of paper may then be retranslated into articulate speech by means of a similar phonographic apparatus and telephone. Its object is, therefore, the same as that of an automatic telegraph, namely, of increasing the capacity of a line by rapid transmission and subsequent retranslation at the receiving end.

The apparatus consists of a transmitter and a receiver; the former is a telephone, the latter is a chemical phonograph of special construction. In appearance it resembles the ordinary original phongraph, but the tin foil is replaced by a piece of tinned paper, and the engraving needle is replaced by a fixed pen, which moves lightly over this paper and is filled with a decomposable liquid; this traces the usual spiral line over the paper. The telephonic line current passes through this pen to the paper and decomposes the liquid in exact proportion to the varying current strength, leaving an indelible record of the oxide of greater or less depth and therefore of proportionate resistances. This record is permanent, and may be removed from the apparatus. To retranslate it, it is placed on a similar phonograph in which the pen is replaced by a light metallic point. A current from a cell is passed through this point to the paper and through a telephone. On turning the phonograph cylinder the variations of the resistance due to the different thicknesses of the oxide on the record produce corresponding variations in the current strength, and thereby reproduce the same sounds in the telephone. Very good results are said to have been obtained, though the apparatus as exhibited has not yet passed the experimental state. It has not yet been used in practice.

Autographic.—The apparatus of Jordey in the French section and that of Edison in the United States section, for transmitting facsimiles of writing or drawings, are already well known and were exhibited in the exhibition of 1881.

Gray's Telautograph.—Among the most interesting exhibits of new departures in telegraphy were two small records of autographic telegraphy exhibited in the personal exhibit of Prof. Elisha Gray, in the United States section, and for which, together with his historical exhibit, he was awarded the high honor of a grand prize. Facsimiles of these two records are given below (Figs. 20 and 21), full size, and will explain themselves.

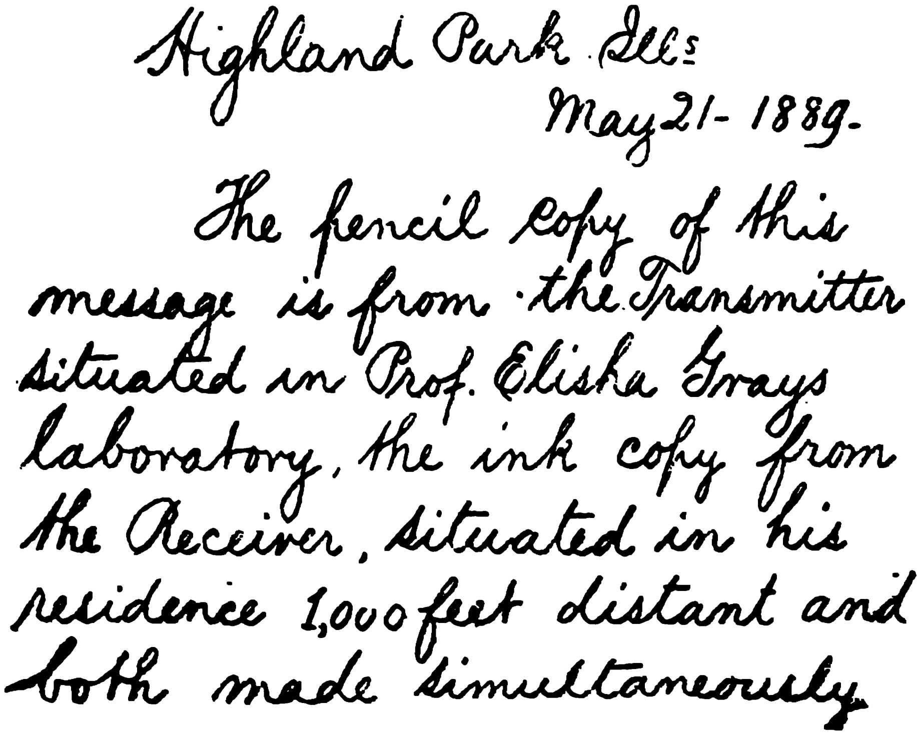
The apparatus, though promised for the exhibition, was, unfortunately, not sent, nor could the writer obtain a description of it, as the inventor was not ready to make it public. All that can be stated here is that the pencil of the transmitter is free to be moved in any direction within the rectangular space, and can even be lifted off the paper and started again at any desired place, thereby permitting line drawings to be sent; the receiving pen will make precisely the same movements. The two facsimiles below will show the almost absolute identity of the transmitted and the original messages. It is believed that two line wires were required, but possibly there was only one. Fig. 20 is the original pencil copy and Fig. 21 the transmitted ink copy.

AUTOMATIC TELEGRAPHY.

The automatic systems, in which the message is prepared in the form of a perforated band, which is then passed rapidly through the transmitter, are coming into use rapidly and represent probably the most important direction of the development of telegraphy. As the main object is to increase the carrying capacity of a line, it is to a certain extent a competitor of the multiplex systems and can in many respects be compared directly with such systems.

Historical.—The idea of the automatic transmission is not new, as was shown by an exhibit by the French telegraph department of an apparatus of Chauvassaigne, of 1865, in which the Morse characters were printed with a resinous substance on a metallic band, which was then passed under a contact brush. The receiver was an electrochemical one. One of the first Morse systems was also an automatic one, the message being set up in types representing dots and dashes, which were then passed under a make-and-break contact.

The most important of these automatic systems is unquestionably the Wheatstone, which is already in use largely in England and, to some extent, in France. With recent improvements it is enabled to transmit as many as [illegible] words per minute, used alone, and 400



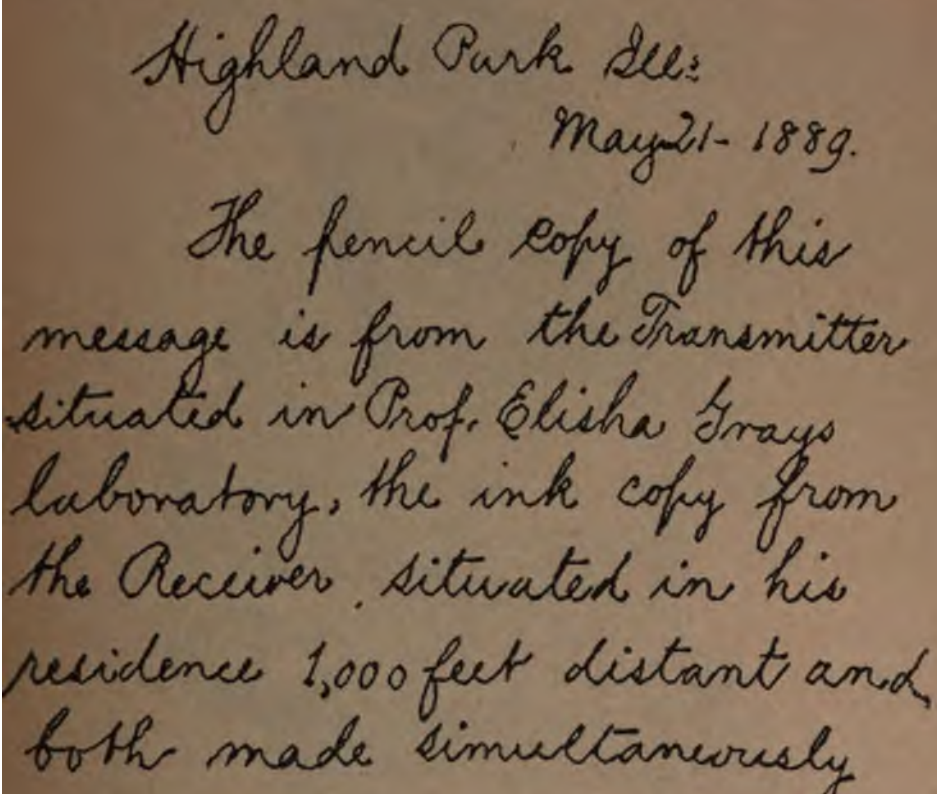
Highland Park Ills
May 21- 1889.

The pencil copy of this message is from the Transmitter situated in Prof. Elisha Grays laboratory, the ink copy from the Receiver, situated in his residence 1,000 feet distant and both made simultaneously

FIG. 3.—Gray's telautograph. The message as sent: pencil copy. For description see page 105.

words when duplexed. The former would replace 30 operators at the ordinary receivers, at 20 words per minute. The normal running rate in England is 300 words per minute. The apparatus was exhibited by Elliott Brothers, of London (British section, grand prize), and represents a very high degree of perfection in fine workmanship, in which it can be compared only with the workmanship in fine watches.

The general principle of the apparatus is briefly as follows: A tape is prepared by the punching apparatus shown in Fig. 22; the three



Highland Park Ill:
May 21- 1889.

The pencil copy of this message is from the Transmitter situated in Prof. Elisha Grays laboratory, the ink copy from the Receiver situated in his residence 1,000 feet distant and both made simultaneously

FIG. 21.—Gray's telautograph. The message as received; ink copy.

knobs represent dots, dashes, and spaces; the middle row of holes (which is regular) is for feeding the tape through the transmitter; the two outside rows represent the dots or dashes according as the two holes are vertically over one another, or as one is in advance of the other.

The tape, thus prepared, is fed into the automatic transmitter shown in Fig. 23, through which it is carried by a rapidly revolving wheel driven by a weight at the rate of 600 words per minute, or about four times as fast as the message could be spoken. The tape thereby passes over two contact springs, which send a positive or negative current to line according as there are perforations on one side or the other; when the two follow one another almost instantly a dot is produced on the receiver, and when they are not over each other a dash will be produced.

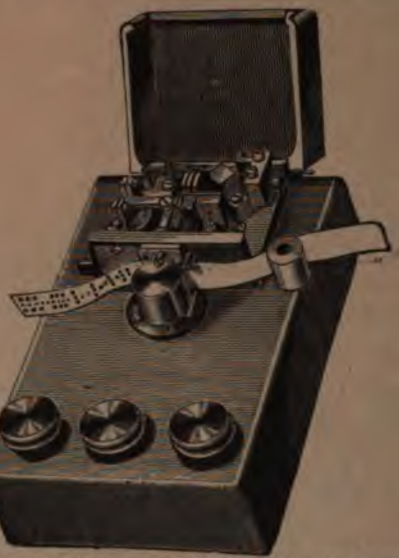


FIG. 22.—Wheatstone perforator for automatic telegraphy; by Elliott Brothers, England.

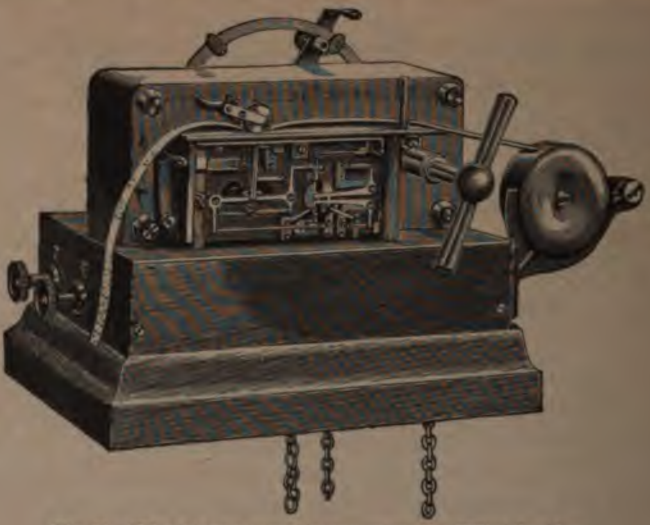


FIG. 23.—Wheatstone automatic transmitter; by Elliott Brothers.

The great rapidity of the succession of the currents is rendered possible by the fact that the line is discharged every time by the reversed current. Sparks at the contacts are avoided by small condensers of one-tenth microfarad placed in derivation between the transmitter and the line.

In the receiver shown in Fig. 24 a tape is, by similar mechanism, drawn through very rapidly, passing under a very light ink roller, which is operated by the receiving magnet. The retarding effect of the electromagnetic inertia of the receiving magnet is reduced by the addition of shunted condensers. For distances over 300 miles relays must be used. The exhibit included these relays, as well as special condensers and resistances for balancing the lines without interruption of the message when the line is working as duplex.

The apparatus, though simple in principle, is quite complicated in construction and can not be described here. For a description of the recent improvements see the paper of Mr. W. H. Preece, read before the British Association for the Advancement of Science, September 5, 1887.

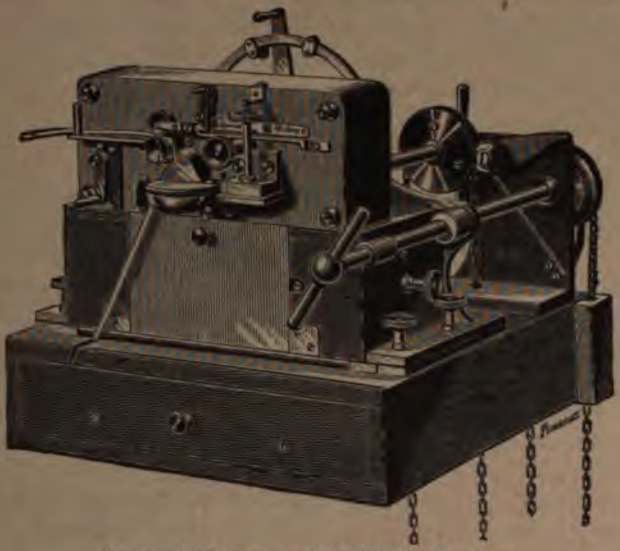


FIG. 24.—Wheatstone receiver; by Elliott Brothers.

Meyer Automatic Repeater.—In the Wheatstone system, if a message is to be retransmitted on another line it is necessary to translate it and perforate another tape, which is a cause of delay and expense and introduces errors. To avoid this Meyer has modified the system so that the receiver not only prints the characters, but at the same time punches its tape with holes, so that it can be passed directly through another automatic transmitter. The ink record is in this system in long and short vertical lines, as in the Herodote system, described above, and is accompanied by the corresponding perforations. It is stated that with this system one hundred dispatches per hour can be transmitted, which, as will be noticed, is very considerably slower than with the Wheatstone apparatus. It has not yet been tried in practice.

Estienne Automatic.—The Estienne system, described above, was also arranged so as to be used as an automatic apparatus with perforated tape. But both this and the Meyer have the disadvantage that the current is not necessarily reversed for every impulse, as in the Wheatstone, and that the speed therefore must be considerably less.

Hughes Automatic.—Modifications were devised by Nault and others by Parment for making the Hughes apparatus automatic. Though ingenious, they are too complicated to be described here. Those of Parment were to a large extent only in the form of drawings.

References.—The embossing system of Edison, and the stenotelegraphic system, both of which are described above, might be classed under this heading of automatic systems. For an automatic transmitter for cables see "Cable telegraphy," below.

DIPLEX SYSTEMS.

In the diplex systems two messages are sent simultaneously in the same direction. Sieur exhibited several methods. In the first a rapidly revolving toothed wheel at the transmitting end connects the line alternately with the positive and negative poles in very rapid succession. At the receiving end these currents pass through a polarized relay with two armatures, one of which will respond to a positive and one to a negative current. Each of the two receivers operated by this relay will therefore respond to the signals from the positive and the negative keys, respectively, at the transmitting end. In the second method a relay has a double armature, one of which responds to a weak current only and one to a strong current. The two keys at the transmitting end send currents of different intensities. In the third method one message is sent by the ordinary direct current and the other by an alternating current. The latter is produced by a tuning fork and an induction coil, and is again transformed in a similar induction coil at the receiver. The phonetic relay at the receiver has a double polarized armature, which in oscillating rapidly, due to the alternating current, will operate a sounder. The alternating current will not interfere with the ordinary direct current transmission.

DUPLEX SYSTEMS.

In the duplex systems two messages are sent simultaneously in opposite directions. In one of the Edison duplex systems, operator No. 1 sends impulses by reversals of the current, which operator No. 2 receives on a polarized relay. Operator No. 2 sends impulses by varying the strength of a direct current, which operator No. 1 receives on an ingenious double balanced relay, which responds only to changes of the current strength in one of the magnets, but not to reversals of the current in both—that is, not to the reversed currents of the transmitter No. 1.

In another Edison system there is an induction coil having two secondary and one primary circuits. The receiver is in the primary circuit. The receiving current passes through both the secondaries in the same direction, and thereby operates the receiver; but the sending current passes through them in opposite directions, and therefore does not operate the receiver. To accomplish the latter, the sending current passes through the two secondaries in multiple arc, through the one to line and through the other to an artificial line.

In still another duplex system of Edison, called the phonoplex, one of the transmissions is by the ordinary Morse system, except that, in addition, a condenser shunts the receiver and the key, which therefore does not affect this transmission. The other transmission is by means of momentary high-tension currents and a telephone, the transmitters and receivers of which must all be between the two Morse stations. The Morse current is too gradual in its action to effect a sharp click in the telephone; while the high-tension current is too small in quantity to affect the Morse receiver. The high-tension current will get to ground whether the Morse key is open or closed, owing to the condenser shunting the key. The high-tension current is produced by a key which makes and breaks the local circuit of a self-induction coil in the line circuit, the extra current from which will pass to line in order to get to ground at both ends, and in doing so passes through the telephone receivers. The second transmission may be introduced between any two points on an existing line. It is used largely in railroad systems in the United States.

Duplex Hughes.—The duplexing of the Hughes apparatus by Terral is not new and has already been exhibited. The system used at present is that of differentially wound magnets.

Phonopore Telegraphy.—Langdon-Davies (British section) exhibited a system of telegraphy by means of an apparatus called a "phonopore." The object is to transmit independent messages over a line while it is being used for the ordinary Morse transmission, without interfering with the latter; also to diplex or duplex the phonopore transmission independently of the Morse transmission, thus enabling three messages to be sent simultaneously over the same wire. This latter was exhibited in operation.

In the phonopore transmission the sending key and the receiving sounder or printer are the same as usual; the special apparatus interposed between the key and the line is called the *phonopore*, and that between the sounder and the line is called the *transformer*. The phonopore consists of an induction coil having one primary wire and two secondary wires. In the primary circuit is placed the sending key, the battery, and a vibrating reed, which therefore enables primary currents of a very rapidly intermittent character to be sent through the coil. One of the secondary coils has one end insulated and the other end to line; the other has one end insulated and the other end to ground. The connection to the line is such that this whole transmitter is to a certain extent in multiple arc with the ordinary Morse sender, but with the important difference that the phonopore branch is *not* connected to ground and therefore does not affect the Morse transmission. The phonopore, however, virtually grounds the rapidly alternating phonopore current by means of the induction or condenser action between the two insulated secondary coils, one of which is to line and the other to ground; this feature is the essential principle of this system, namely, that the phonopore branch is virtually grounded (through an insulator) so far as the phonopore apparatus is concerned, but is not grounded so far as the ordinary Morse transmission is concerned.

The transformer is the receiving apparatus, the object of which is to receive this phonopore current only, and not the simultaneous Morse current. This transformer is connected, like the phonopore sender, in multiple arc to the independent Morse receiver, and is virtually connected to ground through a double-wound induction coil, one end of each of whose coils is insulated just as in the phonopore. It consists of a delicate relay, which is actuated only by an alternating current of the same number of alternations as that from the sending end. This is accomplished by a vibrating diaphragm opposite to an electro-magnet, somewhat as in a large telephone, but tuned to the same number of vibrations, or musical note, as the reed at the transmitter. An alternating current of this frequency only will vibrate this diaphragm, and in doing so the diaphragm, in striking against an ingeniously devised contact, will open the circuit of a relay, which in turn operates the usual printer or sounder.

Duplexing or diplexing of the phonopore transmission itself, independently of the ordinary Morse messages, is accomplished by the usual harmonic system of having the reeds at the two stations of different numbers of vibrations and their respective diaphragms tuned to the same note. All the rest of the apparatus is the same. The advantages of such a system of increasing the sending capacity of existing lines are evident, and need not be enumerated here. In addition, the inventor claims to overcome the delicate balancing or synchronizing in the usual methods of duplexing and to accomplish other useful results by means of his phonopore. A moderately good description, well illustrated, may be found in The Electrician (London), April 5, 1889. The system has been introduced on several lines in England.

QUADRUPLEX SYSTEMS.

The Edison quadruplex system is similar to the first one of his duplex systems described above, in which one transmission is by reversals of current and the other by changing the intensities of a direct current. There are, furthermore, two different strengths of currents used, by means of which this duplex is doubled. The separation of these currents is accomplished by an ingenious arrangement of the two keys and relays at each station as parts of a Wheatstone bridge. It is used largely in the United States. There are said to be over three hundred sets of these in use by the Western Union Company, which, it is claimed, saved them $500,000 the first year, replacing $16,000,000 of extra lines.

MULTIPLEX SYSTEMS.

The principal multiplex system used in France is that of Baudot (French section, grand prize), which has undergone important improvements since the Expositions of 1878 and 1881, and is now in use largely in France as simple, double, and quadruple. Though very complicated in its construction it is, like the Wheatstone automatic, quite small and compact, and in this it differs greatly from the large Hughes apparatus, which it is replacing. Among the recent improvements are the substitution of a small and very ingenious centrifugal regulator in place of the vibrating reed used before; the Siemens relays have been replaced by an original one, by which their number is greatly reduced; the translator, which was previously mechanical, is now purely electric. For a more detailed description, which could not be attempted here, see the technical journals, especially La Lumiere Électrique.

Multiplex Hughes.—Munier exhibited a device for transforming the Hughes apparatus into a multiplex one; the one exhibited being a quadruplex. It is able to transmit 125 letters per minute, and as quadruplex it could therefore transmit about 6,000 words per hour. Experiments made with it between Paris and Dijon proved quite satisfactory.

Radiophonic multiplex.—Mercadier exhibited a multiplex system termed "radiophonic," which belongs to the same class as the well-known Gray's harmonic system, in which the undulating currents produced by a number of vibrating tuning-forks of different pitch are sent through a common line and separated again at the receiving end by receivers of the same pitch, respectively.

In the quadruplex apparatus exhibited by Mercadier, the transmitter is a piece of selenium called the radiophone, on which a ray of light falls; this ray is intercepted by a constantly revolving disk having four series of holes around its circumference, producing four sets of interruptions of the light. This will change the resistance of the selenium accordingly, and thereby produce corresponding vibrations in a current passing through the selenium. These holes are screened by four little movable screens, which can be moved by hand or by a magnet and key. The disk is kept revolving at a constant speed by any convenient motor, its speed being adjusted by an acoustic method. When these screens are moved to imitate the Morse characters, impulses of the undulating current corresponding to that particular note will be sent to line and to the respective receivers.

The receivers are telephones called by the inventor "monotelephones," the diaphragms of which are tuned to the required notes, and rest on three points corresponding to the nodal points of vibrations. They are furnished with resonant boxes and ear tubes. It is stated that these monotelephones will distinguish between sounds differing by as little as half a tone, thus enabling twelve notes, and therefore twelve different messages, to be sent simultaneously. The selenium radiophone may be replaced by a thermic one, in which a microphone is actuated by the expansion and contraction due to an intermittent heat ray.

In another system of the same inventor the transmitters are tuning forks, each with a microphone and an induction coil, as usual.

All these are probably only experimental.

MULTIPLE STATIONS ON ONE LINE.

Limon.—The receiver of the call devised by Limon consists of a toothed wheel, having as many teeth as there are stations on the line; at each station one of these teeth is in connection with the call bell at that station. The wheels at the different stations are all turned together by a step-by-step motion, produced by a succession of positive impulses of current from the transmitting station and received by a polarized relay. When the tooth of the wheel corresponding to the desired station is reached, a negative current is sent to line by the sending operator, which operates a second polarized relay; this closes the local bell circuit of that particular station whose bell is connected to that tooth. This negative current at the same time releases the wheels of all the stations, allowing them to return to zero.

Claude system.—The object of the very complete system of calls devised by Claude (French section, silver medal) is to enable any one station of a series connected on the same line to call any other and then to put itself into communication with that one alone, to the exclusion of all the others, and finally to put the circuits back into their original condition again.

The apparatus at each station consists of a double polarized relay and two dials. The double relay is in the line circuit, and consists of a suspended double bobbin, capable of turning in the field of a strong magnet, one of which bobbins responds to a negative and one to a positive current. The dials are turned by clockwork controlled by this relay. A certain number of positive impulses brings all the dials to the corresponding number; this is followed by a negative impulse, and then by the number of the calling station, after which the two are in communication, all the others being excluded by the fact that their receivers are cut out of the line circuit by their dials. All the dials are brought back by one of the operators by sending a sufficient number of impulses to bring his dial back to zero.

It is used chiefly for railroad and other similar service, in which a number of stations are on one line. It has been in very satisfactory use for a year on the Paris, Lyons and Mediterranean Railroad between Paris and Lyons, a distance of about 320 miles, with eleven stations, on No. 9, B. & S. gauge, iron wire. It is also recommended for similar telephone circuits.

SUBMARINE-CABLE TELEGRAPHY.

Hughes.—The Hughes apparatus was adapted to submarine cables between France and Algeria in 1882 by Mandroux. Though otherwise quite satisfactory in every respect, the speed was only 40 to 45 messages per hour, and it was therefore not kept in service.

Automatic transmission with siphon recorder.—Belz and Brahie exhibited a modification of the Wheatstone automatic transmitter, to adapt it to the siphon recorder. The currents from the transmitter are sent to the cable through a Froment relay. It is said to increase the capacity of the cable from 1,500 words per hour with the siphon recorder alone to 1,800 with the automatic transmitter.

System of working multiple cables.—As parallel conductors in a cable can not be worked independently for greater distances than 250 miles, the Commercial Company (of New York) operate their conductors in pairs as metallic circuits, and using each pair again as part of another circuit, with either another pair or with the earth as return. The chief claim is the perfect way in which this eliminates the inductive disturbances between neighboring wires. This company is the only one having a transatlantic cable ending in New York City, though the line includes a landing in Nova Scotia.

Vibrator for siphon recorder.—The Commercial Cable Company exhibited the Cuttriss vibrator, which is an attachment to the siphon recorder for cables, to replace the usual electrification by high-tension charges, the object of which is to vibrate the ink-recording siphon in order to eliminate the friction on the paper. The usual method has many objections, as it is affected by the moisture or dryness of the air and the paper.

In the Cuttriss magnetic vibrator there is a very small piece of No. 30 iron wire, about one-sixteenth of an inch long, secured near to the end of the siphon. The paper passes over a small iron table, which is the only addition which must be made to the usual instrument. This iron table is magnetized by an intermittent current, causing the end of the siphon to vibrate up and down rapidly, producing a series of dots. The intermittent current is produced by a simple make-and-break magnet, which has a sensitive mercury regulator to adjust the number of impulses to the natural number of vibrations of the siphon; otherwise the siphon would not vibrate regularly.

This system is used on all the instruments of this company and is highly indorsed by them. For a short description and an illustration see Electrical World, June 26, 1886.

Elliott.—Another and simpler vibrator similar to this was exhibited by Elliott Brothers. The siphon was attached by means of a string directly to the armature of the vibrating magnet in the rear of the instrument.

Telephone receiver for cables.—In the cable receiver of Ader the cable is connected to a vibrator which vibrates between two contacts. One of them connects it through a telephone to the negative pole of a grounded battery, the other connects it through another telephone to the positive pole of another grounded battery. A positive current in the cable will increase the sound in the first telephone and a negative that in the other.

Receiver.—For a cable receiver Edison suggests to use his motograph receiver, because of its sensitiveness.

Siphon recorder.—Chamroy exhibited an attachment to the siphon recorder by means of which the writing is done by a succession of sparks from an induction coil, the paper being prepared chemically so as to be discolored by the spark.

Cable relay.—The Eastern Telegraph Company (British section, gold medal) exhibited a relay devised by Brown & Allan to replace the siphon recorder. It consists, essentially, of a small coil suspended by a fine platinum wire, free to oscillate. It has a hollow core, and is placed in the magnetic field between two magnets. A small rod of soft iron, capable of turning with considerable friction around a vertical pivot, is moved by this electro-magnet. When the cable current passes through this electro-magnet it turns it to the right or left, which moves this rod up to a contact, where it remains, while the coil continues to the end of its oscillation. This contact closes a local circuit working a Morse receiver. It is used largely by this company for their submarine cables.

ACCESSORIES.

Keys.—The Arnaud key has two sets of contacts at each end of the rocking lever, the connections of which are such that the depression and releasing of the key will connect the positive or negative pole, respectively, to line and at the same time connect the other pole to earth, thus reversing the current for each impulse.

In the discharge key of Schaeffer, one end of the key lever is long, so as to increase the amount of motion, and has a spring attached to it, which at every motion up or down of the key touches, in passing, a contact connecting the line to ground, thereby discharging it before and after every impulse of current.

Farjou (French section, bronze medal) exhibited a number of keys for various purposes, which have given very satisfactory results. The first is for automatically connecting the line to ground for a moment only every time the key is released or raised. This is accomplished by a small movable ball which rests on a spring, which keeps an earth contact open. Every depression of the key strikes this ball, causing it to roll up an inclined plane, thereby relieving the spring of its weight and closing the earth contact of that end of the line. The ball, in returning, a moment later, opens the earth contact and the line is again ready for the next impulse.

In the double discharge key the line is not only put to earth as described, but a discharging battery is also put to line for an instant between the position of transmission and that of repose. This is accomplished by a sort of fork, one of the two prongs of which is touched by each motion of the key (the lower one being insulated), and by an ingenious snap spring the contact made thereby is broken immediately afterward. This fork is one pole of the discharging battery, the key lever being the line terminal, as usual.

In the compensating double discharge key the impulse of the current is divided into two parts immediately following one another, the first being that of the whole battery and the second that of a smaller battery. This is accomplished by a second snap-fork contact similar to the one just described, but closing the momentary contact of the whole battery during the downward motion of the lever, while the other acts during the upward motion.

Relays.—Sambourg exhibited a polarized relay requiring no regulation. Instead of polarizing the armature four electro-magnets are used, two of whose cores are connected magnetically to a permanent magnet, which gives to these cores a polarity opposite to that given to them by the line current which flows through all four. The attraction of these two is opposed to that of the other, and the one common armature will therefore move toward one or the other according to the direction of the current.

In the relay of Dutertre the core of the relay is polarized by an external fixed magnet, and is capable of turning under the influence of the current in the coil. In that of Mandroux the polarized armature is between four magnets, which are wound so that those facing each other are always of relatively opposite polarity, and those adjacent are of like polarity.

In the Baudot relay the coil is at right angles to a permanent magnet which supports the axis of the armature. The action of the magnet is normal to the axis of the armature, and the action of the electro-magnet is normal to the armature.

Motograph relay.—The Edison motograph relay is based on the fact that the friction of a sliding contact on a revolving cylinder of some porous material wet with potash is greatly diminished while the current passes. This cylinder, driven by clockwork, pulls a sliding brush by friction against the action of a spring. When the current passes, the friction diminishes, the spring predominates and closes a local circuit. It has the advantage that it is free from remanent magnetism and extra currents.

In his carbon relay the pressure produced by the magnet on a carbon button changes its resistance and thereby actuates a local circuit.

Reference.—For cable relay, see Cable telegraphy, above.

Receivers.—Among the receivers exhibited was a Morse receiver of Oudin, very light and compact, containing in it all accessories, including ten moist cells; another of Dini, of strong and rigid form and economical construction. The Morse receivers of the French administration are the same as those of 1878.

Sounder.—The Decamp sounder consists of a telephone in which the diaphragm in vibrating makes and breaks the current of its own magnet, like an electric bell, thereby producing a musical note to replace the click of the usual sounder.

Discharging device.—Godfrey (French section, silver medal) exhibited an ingenious and very simple system of discharging lines, which is said by good authority to be the best of all similar systems. It is for use chiefly for underground, submarine, or long aërial lines having considerable capacity. It consists simply of a coil having very great self-induction, which is connected from line to earth at each end, therefore in derivation to the battery and key, or receiver and key, of the ordinary Morse systems, according as it is the sending or the receiving apparatus. It has increased considerably the efficiency of the lines on which it is used and has replaced a number of relays which were formerly considered indispensable.

Artificial lines.—Clark, Muirhead & Co. exhibited their well-known artificial lines which are used in duplexing the submarine cables. They consist of strips of tin foil wound so as to act both as condensers and as resistances combined, similar to a line.

Automatic ground alarm.—The object of a device of Caréme & Hajean is to sound an alarm in case the line is grounded accidentally, and is of use specially when a number of lines are operated by the same battery. It consists of a coil wound around a bar of zinc. It is placed between the battery and the key. If the circuit is accidentally grounded beyond the key, this coil will heat sufficiently to cause the zinc rod to expand and close a local bell circuit.

Dynamos for telegraphy.—Picard exhibited a system for replacing the batteries by a dynamo. The dynamo circuit is closed through a resistance of German silver wire, the middle of which is connected to ground. This resistance is then treated just as though it were a series of batteries, the currents for telegraphing being led off from different parts of it in accordance with the number of volts required, and from the right or left of the ground according as they are to be positive or negative. To avoid accidents due to grounds or short circuits, each of these multiple arc branches leading off from this resistance has a separate resistance in its circuit which is proportioned at the rate of 4 ohms per volt of the potential, so as to limit the greatest possible current to one-fourth of an ampère. The system exhibited was one for 100 volts and 10 ampères. The system is in use at the central office in Paris and is proving itself to be very satisfactory. The inventor estimates the economy as follows for a 6 horse-power machine: At 0.1 franc (2 cents) per horse-power hour, it will cost 14.40 francs per 24 hours, or 5,256 francs (about $1,000) per year, for a station like the central station of Paris. The equivalent, 10,000 cells, would cost 30,000 francs per year.

Wires.—For the requirements and tests of the galvanized iron line wire delivered to the French Telegraph Department. (See under "Wires, cables, and conduits.") Copper wires have been used by this department for several years. For telegraphic lines, copper wires of 2 to 2½ millimeters have replaced those of iron of 4 and 5 millimeters; for telephone city circuits eleven-tenths millimeter is used; for long distances it varies, that from Paris to Marseilles, for instance, being 4½ millimeters. Copper wires are required to have a resistance of less than 21.4 ohms per kilometer at 0 C. for a diameter of 1 millimeter. It must support a tensile strain of 40 to 42 kilograms per square millimeter, with an elongation of not more than 2 per cent. A wire of 2½ millimeters diameter must stand seven bendings in a vise.

For a description of the underground cables for the city of Paris, see "Wires, cables, and conduits."

TELEPHONY.

GENERAL.

As there is no fundamental patent for telephony in France the natural result is that the telephone, as an apparatus, is being developed much more rapidly there than in this country. There is much wholesome competition both among inventors and among makers; the telephones are consequently better, cheaper, and as they can be purchased by anyone they are coming into use very largely in private installations. The latter was particularly noticeable to an American. Almost every exhibitor of electric bells and annunciators had his system of house telephones; some at the exceedingly low price of a few dollars for two complete sets. They appeared to be as common as exhibits of electric bells and annunciators, and are being introduced about like these. Some makers are introducing them by thousands. Such systems are almost always two simple magneto telephones (without a battery) both as receivers and transmitters; or in some there is a simple microphone transmitter connected directly to line without an induction coil. In the best systems for longer distances the microphone is always used with the induction coil.

Progress.—The telephone as a receiver may be said to be one of the few inventions which have remained in practically the same form in which they were born. The telephone receivers used at present in the United States, England, and France are practically the same as those first introduced in the United States; they have been modified only very slightly in their proportions. Many radical changes and improvements have been suggested and are used, but by far the largest number in the large exchanges are still of the original types. As a transmitter it has given place to the microphone, except for very short distances.

Most of the progress in the instruments was made prior to the exhibition of 1881; that made since has been mostly in the systems, in the details, in the proportion of the parts, and in their improvement for special purposes, such as for long distances, etc. As a commercial apparatus it may be said to have been developed almost entirely since the last international exhibition in 1878.

Telephone systems in France.—The systems and apparatus are much better than in this country, the transmission being very clear and distinct. The transmission of music from places of entertainment is particularly fine and clear, especially in the installation at the exhibition. The *service* in the city of Paris, on the other hand, is exceedingly poor and far inferior to ours, especially since the Government has taken possession of the exchanges. The answer to the calls are so long coming that one does not generally wait at the telephone itself for this answer. For important messages within the city limits a messenger in a carriage is still frequently preferred to the telephone. One of the causes of delay is that the city is divided into numerous subcentral stations connected by trunk lines, and it is necessary in many, if not in most calls, to retransmit the call to another station. The Government has recently taken possession of the telephone service; the immediate result was a great increase in complaints of poor service; but it is too early at present to draw any conclusions as to the inadvisability of the Government owning and operating the telephone service.

Telephony in the United States.—Telephony being, even more than telegraphy, a monopoly in the United States, the wholesome effects of competition do not exist, and little progress can therefore be expected at present other than such as will enrich the companies. The service, as distinguished from the apparatus and systems, is probably better than in other countries, but even at its best it often leaves much to be desired. The apparatus and systems are, however, inferior to those of France. The transmission is not nearly as clear and distinct, and the circuits are much more subject to interferences and to interruptions. One explanation, and not an unreasonable one, why improved apparatus is not being introduced more rapidly is that there is such a very large number of apparatus in use already that to change it all would be an unwarranted outlay of enormous proportions; besides, a change in apparatus often involves a change in the system. One result of the monopoly, which is much to be regretted, is that private installations and house telegraphy are practically prohibited here. In France the private telephone is in common use, like the speaking tube; here it scarcely exists.

Exhibits by countries.—Exhibits in this class were confined entirely to the French and United States sections. In the former they were very common, the finest and largest being the excellent exhibit of the Société Générale des Téléphones (grand prize), who have until quite recently had complete control of almost all the telephone service of France until it passed into the hands of the Government in September, 1889. Among the other French exhibitors the one most prominent, and especially noted for excellent workmanship, was Branville & Co. (gold medal). In the United States section were the large and very creditable exhibts of the Bell Telephone Company and the Western Electric Company, which attracted much attention among European specialists; the others were historical exhibits of the researches of Edison and of Gray.

Detailed description.—The accompanying detailed description has been limited to a very brief one, as this branch, not being public property here, is of little interest to the electricians in general.

Historical.—The historical exhibits of telephones were confined almost entirely to the United States section. The Western Electric Company included among its exhibits quite an extensive historical collection of American telephones. It was confined almost entirely to the different commercial forms and not to experimental models. Among them was one of the first commercial telephones, consisting of a U-shaped magnet, having two parallel soft iron pole pieces, around which were wound the bobbins. The diaphragm was not attached to either; that is, it was not polarized, strictly speaking, but was under the influence of both poles combined. In the Edison exhibit there was also a historical collection of experimental telephones, showing the researches of Edison in this field. Illustrations of these, but not accompanied by a technical description, will be found in the Electrical World, October 5, 1889, p. 234. In the personal exhibit of Elisha Gray were shown the original water telephone described in his caveat of July 14, 1876; also his tone receiver of 1874 and the one of 1876, made for the Centennial Exhibition; also his strap and his violin receiver, both of 1874.

In the exhibit of the Société Générale des Téléphones were a large number of historical apparatus of the very extended researches of Ader. Among these was an old Reiss form of receiver, consisting of a simple electro-magnet having a block of wood secured to the one end of the core and a handle to the other end. The longitudinal vibrations of this core, due to the rapid changes of magnetization, are communicated to the block of wood. It is said to talk very well, even without an induction coil in connection with the microphone transmitter.

RECEIVERS.

Ader.—The receiver of Ader, exhibited by the Société Générale des Téléphones, is shown in Fig. 25. The magnet is in the form of a circle, which answers at the same time as the handle of the instrument. On its two poles are secured the soft iron pole pieces, around each of which are placed the bobbins, B B. The case, O, inclosing these, forms a resonant air chamber, closed at the top by the soft iron diaphragm, M M, which is secured at its periphery by the trumpet-shaped cap, E. In the latter, and quite close to the diaphragm, but not touching it, is secured a soft iron ring, X X, which is called the exciting armature. The caps are of hard rubber, and all the metallic parts are nickel plated. Two of these are usually used in each installation, one for each ear.

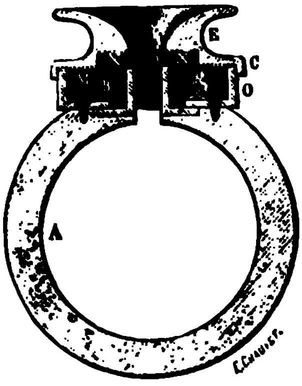


Fig 25.—Ader's telephonic receiver

This is the receiver which is used almost exclusively in all the telephone exchanges in France; besides being very simple in construction, it is an excellent receiver as such. It appears to be especially good for the telephonic reception of music. With the exception of the exciting armature, X X, it is identical (except in proportions) with one of the first commercial forms used in the United States, and exhibited as a historical model by the Bell Telephone Company.

[illegible]—The magnet in the Ochorowicz receiver is in the form of a long hollow cylinder, split longitudinally and having its two poles at these edges, to which the two parallel soft iron pole pieces, surrounded by their coils, are attached nearly radial to the cylinder. There are two parallel diaphragms, one, as usual, above the two pole pieces, and the other next to the magnet, and below the

coils, fastened to the magnet at one point only, and having two holes larger than the coils which pass through it, so as to allow it to vibrate. These two diaphragms are connected together by a ring at their outside edge forming a sort of flat box, which augments the sound by virtue of its resonance. In the form exhibited by Hutinet there are two separate diaphragms acted upon by the same magnets to increase the resonance. By means of a short flexible tube and mouthpiece attached to the one in the rear, the same telephone may be used as transmitter and receiver, for short distances. In the Aubry form with two diaphragms, the magnet is very small and light, in the form of a closed horizontal ring having two projections in the inside containing the vertical pole pieces and coils. This ring magnet is attached to the center of one diaphragm of German silver. This will therefore vibrate together with the other diaphragm (which is, as usual, magnetic and opposite the poles) and will reinforce the sound. It is said to be particularly sensitive.

Concentric poles.—In one of the d'Arsonval forms the two poles are concentric, one being a cylindrical core and the other of annular form encircling it. In another the magnet is somewhat like the form of the letter S, the two poles terminating respectively in a cylindrical core and an annular piece encircling it. In one of the Testor forms the poles are concentric, and the diaphragm has a hole in the center below which is a concave reflector to reflect the sound.

Polarized diaphragms.—In the Colson form the diaphragm is between two magnets, one of which polarizes it and the other acts as usual on the diaphragm. In the Pollard form there are a number of small horseshoe magnets with like poles at the center connected to the soft iron pole pieces; the other poles are connected to an iron ring to which the diaphragm is secured by its circumference. In the Sieur form the magnetic disposition is similar, but it consists simply of a bar magnet having one pole at its center and two like ones at the ends, which latter touch the outside edge of the diaphragm.

Almost all of the last three groups of telephones were made and exhibited by de Branville & Co. (French station, gold medal).

TRANSMITTERS.

Most of the above-described receivers are used also as transmitters for short distances on private lines.

Microphone transmitters.—The transmitter of Ader exhibited by the Société Générale des Téléphones is shown in Figs. 26 and 27. The first shows a complete telephonic installation, of which the microphone is the horizontal slab. The second is a view from below up, showing the carbons of the microphone, and the induction coil. The microphone consists of a thin horizontal plate of deal 2 millimeters thick resting on a frame of soft rubber to deaden the mechanical vibrations communicated to it from the apparatus. On the lower side of this wooden diaphragm are secured three crosspieces of carbon, *d*, *b*, and *c*. The twelve cylindrical carbons, E E, rest loosely in holes in these cross pieces, forming twenty-four contacts, which may be connected, as shown, four in series and six in multiple, or, by connecting one lead to the center pieces and the other to the two end pieces, they may be coupled two in series and twelve in multiple. This is the transmitter used almost exclusively in the telephone service in France. The same form is used also for the transmission of operatic and concert music in Paris.

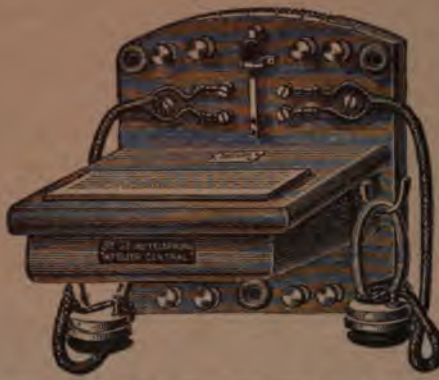


FIG. 26.—Ader's microphone transmitter. Front view.

In the microphone of d'Arsonval & Bert the rods of carbon have a ring of thin soft iron around their center. Opposite to these is a magnet which exerts a certain elastic force on these loose carbons and which is claimed to prevent some of the objectionable noises which so often accompany the transmission. In the form devised by Abdank-Abakanowicz there are four little carbon disks which rest, in vertical planes, loosely on their periphery on a slightly inclined flat piece of carbon on one side and against a thin piece of carbon on the other side. The latter piece of carbon is on the back of the wooden diaphragm. Their weight keeps them in contact with both. The vibrations of the diaphragm tend to roll these up the inclined plane on the opposite side, which keeps turning the disks so as to keep changing the points of contact. These four disks are connected two in series and two in multiple arc. In the Lagache form there are short carbon bars hinged at one end by a carbon rod which passes loosely through a hole in the bars, their other end resting loosely on a carbon plate. In the Mandroux & Pecquet form there are two separate microphones on the diaphragm, each of which has

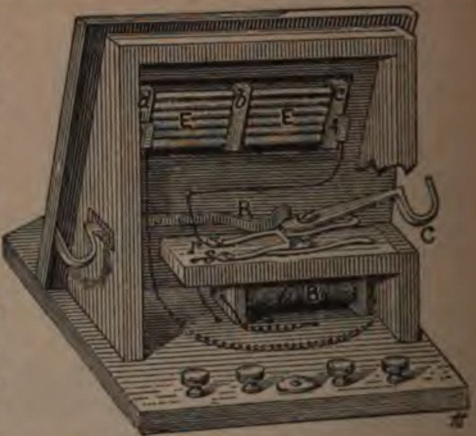


FIG. 27.—Ader's transmitter. View from below.

its own independent battery. The induction coil has one common secondary and two primaries, one for each microphone. It is said to be used especially for long-distance telephony. In the Van Rysselberghe form for long distances, the eight microphone rods are all connected in multiple arc to obtain as low an internal resistance as possible. In the Breguet form there are six radial rods, all having one end supported by one common block in the center of the diaphragm, the other ends being supported around the periphery.

Powdered carbon.—The American Bell Telephone Company exhibited a transmitter made of a layer of powdered carbon between two thin disks of platinum. It is always in a vertical position. When the powder has settled or has become packed it may be loosened by shaking the apparatus. It is used in the United States on their long-distance lines. The Hipp form (Swiss section) is very much like this, only that the box is not quite filled, so that by turning or inclining it one can loosen the material. This box is placed inside of another box having a mouth piece, the axis of the disks being perpendicular to that of the mouthpiece; over the inside end of the mouthpiece there is a stretched membrane of parchment; the sound waves act on both sides of this microphone, thereby increasing the actions. Up to 25 and 30 miles this can be used without an induction coil and gives excellent results. It is used in Switzerland and Italy. In the Berthon form there are two parallel disks of carbon separated slightly from each other; a portion of the space, bounded by a cylinder of hard rubber, is filled with grains of retort carbons; on inclining the apparatus these come in contact with the upper plate and form a microphone. In the microphone of Waden (Finland section, bronze medal) there are two parallel diaphragms of carbon close together; one is connected to the diaphragm proper and vibrates with it; the other is fixed. One of them has a number of grooves on one side, in which are placed about fifty little carbon cylinders 2 millimeters in diameter and 3 millimeters long. These are held in place by the grooves and form the microphone contact between the two, when they are in an inclined position.

Ader long-distance telephone.—In the long-distance telephone of Ader there are two carbons secured together and to the diaphragm, but separated from one another by a short space, and insulated from each other. In the space between them rests a wedge-shaped piece of copper, platinum plated, making contact with both of these carbons. One carbon being secured to the vertical diaphragm and the other being some distance back of it, the line through the contacts is perpendicular to the diaphragm. When the diaphragm vibrates it increases the pressure on one of these contacts and diminishes that on the other, and vice versa. The current enters by this copper contact and divides into two branches; these pass in opposite directions through the two primary coils of a three-wire induction coil, the single secondary of which goes to line. The effects of the currents from the two microphones will consequently be in the same sense and the induction in the secondary will be proportional to their sum.

ACCESSORIES.

Switch boards.—The subject of switch boards is one ot the few branches which are of interest only to a few specialists, and not to the electrician in general. A description of such apparatus is therefore of no interest unless given very completely with all details, which would not be possible in this general report. Furthermore, specialists are better able to study the subject from published detailed and illustrated descriptions than they would be from a general and brief report like the present. It was, therefore, thought useless to give here more than a mere mention of the chief exhibits in this branch.

The largest and most complete switch-board exhibit was that of the Société Générale des Téléphones. The exhibit included several sections, or "units," of a multiple switch board for 3,000 subscribers, and is the type to be used in the Paris service. It is very complete in all details, but is necessarily very complicated. Each of the 15 sections forming the complete board for 3,000 subscribers embraces 200 subscribers, and requires two attendants, one for each 100 subscribers. Each attendant can connect any one of his 100 subscribers to any of the 3,000, directly as the terminals of all the latter are within his reach in his or in one of the neighboring sections. Trunk lines connecting the several central stations are connected to the switch board the same as subscribers. Each central station is connected to each of the others, by a number of trunk lines; only in very few cases would two trunk lines be necessary for one connection. All the circuits are double wire, or metallic circuits, but the switch board is said to occupy no more room than if the circuits were single wire or grounded, as is usual in the United States. All the calls are battery calls; no magnetic ones are used. Lalande batteries are used altogether, three cells for a microphone, and twelve to fifteen for a call. Among the details are means permitting the attendant to connect himself in multiple arc with a circuit in use in order to hear whether the conversation is going on, and another connection in series permitting him to hear and also to speak; also another enabling him to find out whether a trunk line is in use or not without interrupting the conversation, should it be in use.

The Western Electric Company (United States section) also exhibit a section of a multiple switch board for double wire circuits, such as is used here for the long-distance lines. It is, in general, similar to the one mentioned above, but differs in its details.

Mandroux (French section) exhibited a simple board for fifty subscribers, for single line circuits.

Sieur (French section) exhibited a number of switch boards for single or double circuits. One of the characteristic features is that all connections are made by means of hooks at the ends of flexible cords. There are one, two, or four of these at the end of each cord, depending on the number of connections to be made simultaneously.

Calls.—In the call of Sieur a brass wheel, with iron teeth on its periphery, is made to turn so that the teeth pass by a polarized electro-magnet. The alternating current generated is sufficient to produce a sound in the telephone audible several yards off. Zigang's electric trumpet consists of a diaphragm at the bottom of a trumpet-shaped tube, which is vibrated by the action of the electro-magnet, like in a telephone, the current being made and broken by the diaphragm itself, as in a bell. In the call of Sieur & Van Rysselberghe, the telephone is used as a sort of relay to operate a local bell circuit. A contact made of a sort of pendulum resting against the diaphragm, is in shunt circuit to the bell; when the membrane vibrates, this contact becomes a poor one and the greater part of the current goes through the bell. The vibrating current is produced at the sending end by a push button and an ordinary vibrating interruptor.

SYSTEMS OF TRANSMISSIONS.

Several telephones on the same circuit.—In the system of Berthon, of the Société Générale de Téléphones, two subscribers on the same metallic (double wire) circuit are enabled to call each other without calling up the central office. This is accomplished by a second call button at each of these two telephones, which connects one of the lines with the ground, forming a circuit independent of the other metallic circuit. A bell at the other subscriber responds to this grounded circuit, but the annunciator at the central station, being on the metallic circuit, does not respond. The system of Ader permits the central station to call any one of the four subscribers on the same metallic circuit. The line is grounded at the middle of the loop, leaving two subscribers on one side and two on the other. At the central stations there are four calls from a grounded battery; one sends a positive current and another a negative current to one-half of this loop; the other two send a positive and a negative current to the other half of the loop; the calls at their four subscribers respond, respectively, by means of polarized relays, to one and only one of these currents. In the Sieur system for three subscribers, one annunciator responds to a positive grounded current, another to a negative grounded current, while the third responds to a current on the metallic loop. In the Sieur system for four subscribers, two of the annunciators respond only to a weak current, one to a positive and one to a negative current; the other two respond to a strong current, one to a positive and one to a negative current.

Telegraphing and telephoning on the same circuit.—In the system of Van Rysselberghe the telegraph currents are made to vary gradually instead of abruptly, in which case they will not be heard in the telephone; furthermore, their succession is insufficiently rapid to produce a note. This is accomplished by electromagnets in circuit between the receivers and the line, and by condensers having one of their poles to line and one to ground; furthermore, by a condenser of one-half microfarad, called a separator, between the telephone and the telegraph line; two of these are used when the circuit is metallic. These condensers form a screen to the telegraphic currents, but allow those from the telephone to pass. Up to 200 kilometers (125 miles) iron wire can be used, but for greater distances bronze wire is essential; the size varies from 2 millimeters for 250 kilometers, to 5 millimeters for 2,000 kilometers. This system is used in France on interurban telephone lines between Paris and Rowen, Havre, Lille, Rheims, and others; also Paris to Brussels, and on 7,466 kilometers (over 4,600 miles) of lines in Belgium. It is also used in many countries in Europe and America, including the United States. In the Maiche system for metallic circuits only, there is an induction coil with three circuits at each station. The microphone current passes through the one primary; the two secondary coils are connected in series and close the end of the loop of the metallic circuits; this completes the telephone connections. One end of the telegraph circuit is grounded and the other passes to the junction of the two secondaries, and thence through both in multiple arc to the two lines, which latter are therefore in multiple arc as one line; the currents in these two branches of the telegraph line then pass through the two secondaries in opposite directions, and will therefore have no influence on the primary at the receiving station, which contains the telephone receiver. Trials were made in 1885 on several of the long-distance telephone lines in France.

Domestic telephone systems.—Private telephone systems, for private houses, factories, etc., are developed to a very much greater extent in France than in the United States, due to the fact that there is no fundamental patent there to interfere or to make such use practically prohibitory by high royalties. Exhibits of such telephones were very numerous in the French section. They are as a rule simple magneto telephones, without battery or microphone. Some are with microphone but without induction coil. There is very little of special interest regarding them, to be described here.

Operatic telephone transmissions.—In the exhibition building of the Société Générale des Téléphones, there were a large number of telephones connected with the opera house, and several other places of amusement where the entertainment was entirely of a musical nature, as distinguished from that in the theaters. The system was a double one, there being two microphones on the stage by the front footlights, one to the right and one to the left; these were connected by independent circuits, each to a series of telephones at the receiving station; each listener had two telephones, one on each circuit. There were about twenty to thirty sets of these on one line. The circuits were all underground, and metallic, some being a number of miles long. The transmission was remarkably perfect and clear, and there was an entire absence of the objectionable by-sounds. The transmission was equally good for instrumental as well as vocal music; a person skilled in orchestral music could not only distinguish readily between the string and the wind instruments, but could even distinguish between those of the same class, as for instance between a flute and a clarionette.

MISCELLANEOUS.

To an American, one of the most prominent features of the whole telephone exhibit was the very large number of modifications in the forms of apparatus, having the general object of making it more convenient for the persons using it. Especially interesting were those exhibited by the Société Générale des Téléphones. Among these may be mentioned the desk form shown in Fig. 28, which comprises a whole installation. It is on rollers and may be moved about at will. The microphone forms the top slab of the apparatus, and is slightly inclined; the two telephones are the receivers; the small push button in front is the call (battery call). Another convenient form known as the Berthon form is shown in Fig. 29, in which the receiver and transmitter are connected together by a convenient handle so that the former is at the ear while the latter is at the mouth; the relative positions may be altered slightly by adjusting screws. The call button and switches are comprised in the small wall fixture. This form is used largely for desk work, or on shipboard, or in general, when the person talking can not remain in a fixed position in front of a fixed microphone. In another form the receiver was attached to a long handle which enabled the user to rest his elbow while holding the apparatus. In some of the wall instruments two small ornamental brackets, each having a small cushion, were fixed at the two sides of the apparatus to enable the listener to rest his two elbows while

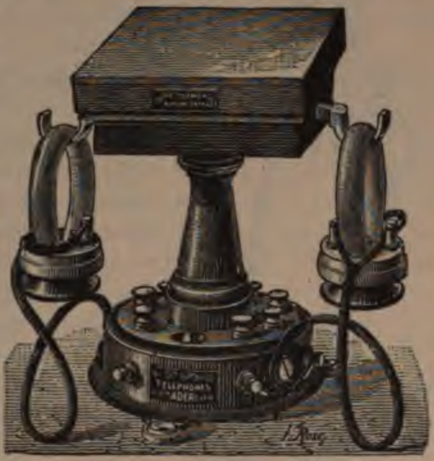


FIG. 28.—Telephone apparatus; by the Société Générale des Téléphones.

holding the two receivers to his ears. In another form the apparatus was accompanied by a small writing tablet for taking notes while listening or talking. In another, the trumpet-shaped ear pieces of the receivers were made of thin soft rubber in place of the usual hard rubber, making it much more comfortable for the listener, for long conversations.

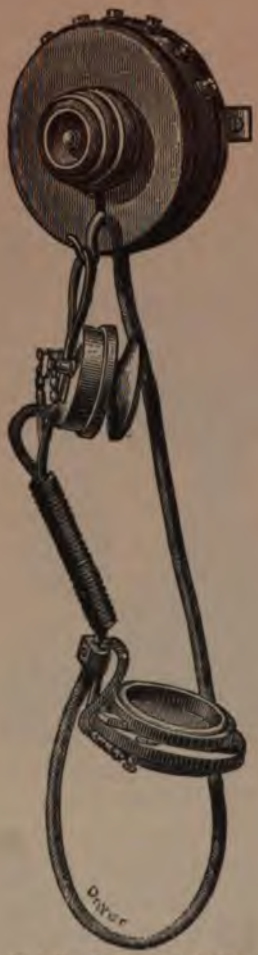


FIG. 29.—Berthon's telephone apparatus.

Among other exhibits were complete installations for use on shipboard. These were inclosed in tightly fitting iron boxes, and were especially well insulated against moisture; the switches and calls were so arranged as to obviate the use of a central station, each operator being able to call any other directly.

There were also a large number of exhibits of private telephone systems, such as for domestic purposes, for factories, large establishments, etc., accompanied by the necessary annunciators and calls, to enable one person to call any other directly. In general, there were many exhibits of this kind showing great progress in the adaptability and use of the telephone abroad, progress which can not be looked for here in the United States, the birth place of the telephone, until the broad fundamental patents have expired.

Apparatus for divers.—In the French naval department there was exhibited an apparatus devised by Auger for the use of submarine divers. It consisted essentially of two small telephones united by a curved, flat spring which passed around the head and held the telephones to the ears. To the same spring was attached a microphone, which was thereby held in front of the mouth.

Theatrophone.—The Société Générale des Téléphones exhibited the theatrophone of Marinowicz. This was a somewhat complicated but very complete public telephone receiving station, which was always connected with a transmitter at some musical entertainment. It was operated by dropping a 50 centimes (10 cents) silver piece into a slot, which puts the telephone in circuit. After five minutes the mechanism automatically cuts it out. A company is introducing these in Paris, and provides a continuous musical entertainment at the transmitting station.

Telephonograph.—In the Edison exhibit was shown a telephonograph which consists of an automatically acting phonograph attached to a telephone receiver, for the purpose of recording a telephone message on the phonograph in the case when no one is present to receive it. From this phonograph record it can then readily be reproduced when the person for whom it was intended returns.

Telephonographic transmission.—A different system, though somewhat similar in its object, devised by Lambrigot, will be found described under the heading "telegraph," to which it more properly belongs.

In this connection it may be of interest to call attention to an experiment exhibited at the Franklin Institute, in Philadelphia, in the winter of 1888–'89, by Mr. Hammer, in which a cornet solo was played into an Edison phonograph in New York city; from the phonograph it was transmitted by microphone over a metallic circuit to Philadelphia, where it was received by an Edison motograph receiver and recorded on another phonograph; from this it was then reproduced so as to be audible to an audience of several hundred people in a moderately large lecture hall.

Cryptophone.—The object of the cryptophone, devised by Henry & Berthon and exhibited in the French war department building, is to enable a person to keep watch secretly over a distant building or district. It depends for its action on the vibrating or trembling of the ground or walls of a building caused by a moving object. The cryptophones proper consist of delicate contacts connected to microphones and situated at the respective places. The cryptophonoscope is a sort of annunciator at the receiving station to which the microphones are connected by separate wires. Any vibrations at the microphone cause the respective annunciator to ring an alarm and operate a drop. By means of telephones the watchman can then listen to the nature of the noises. It is applicable chiefly for military purposes.

Telephone bullet probe.—The Western Electric Company exhibited a telephone bullet probe and induction balance, for locating the position of a bullet or other metallic masses in the human body. The apparatus is called Dr. Girdner's, and is said to have been invented by Professor Bell; the balance is known by the name of Hughes. The balance is for the purpose of determining the part of the body under which the bullet is, while the probe is for finding its depth below the skin. A well illustrated, though not very technical, description will be found in the New York Medical Journal, April 9, 1887.

For the electrodynamometer for measuring telephone currents, see "Measuring instruments."

III.—ANNUNCIATORS, ALARMS, BELLS, CLOCKS, GAS LIGHTING, ETC., AND MISCELLANEOUS APPLICATIONS.

ANNUNCIATORS.

Judging from the large number of exhibits of annunciators in the French section, they appear to be coming into use almost as much there as in the United States. Although there were numerous different forms shown, there is little of interest to be described here.

In the ordinary forms of the mechanism of annunciators, the greatest force required by the movable armature of the magnet, is when it is farthest from its magnet, in which position the magnetic force is smallest. This disposition is evidently not the most rational one. In the annunciator devised by Abdank-Abakanowicz and exhibited by Postel-Vinay, this disposition is more rational and therefore requires less battery power. The armature is connected by a spring lever to a small hammer which strikes and trips the signal disk just as the armature is about to touch its magnet; that is, at the moment when its force is a maximum. It has no work to do until the magnetic force is greatest, when the hammer acts by its accumulated impact.

An annunciator for hotels exhibited by the Western Electric Company (United States section) was provided with return calls, by means of which the receipt of every call can be announced to the sender by a return signal to the respective room. The push buttons on the annunciator were furthermore arranged in a circle, and were provided with a common lever arm which, when moved around in a circle, will press each of the buttons in succession. The object of this is to sound a general fire-alarm signal throughout the whole hotel and in each separate room and corridor. This lever arm, being actuated by a strong spring, need merely be released, and will then continue automatically to ring all the bells in succession. The system requires a double circuit for each room.

In several of the annunciators exhibited in the French section polarized armatures turning between two magnet poles were used to turn the signal disks. Reversing the current, by means of a push-button in connection with the annunciator, sets them back again ready for the next call. The chief advantages claimed are that they are less likely to get out of order than those having drops and catches, and that the dials can be reset from a distance. A disadvantage is that two magnets are required for each dial in place of one. Among other annunciators was one in which the number of the call was registered on a counter. In another, called a night annunciator, a small electric light was automatically lit behind the respective transparent dial whenever a call was received.

Fire annunciators.—There were exhibited a number of devices for automatically indicating by an alarm the presence of fire in a building. Most of these were slight modifications of the usual and well-known forms, and are not of sufficient interest to be described here.

Among the simplest was one in which a small spring was held back by a plug of some readily fusible metal, which, when melted by the heat, allowed the spring to expand and thereby to close a contact.

Still simpler and more practical is the form exhibited by J. Hutinet (French section), which consists simply of a double insulated wire composed of two small copper wires very heavily tinned, one of which is insulated from the other by a thin coating of soft rubber, the two together being then wound with cotton, covered with rubber, and an exterior coating of cotton or silk of any desired color to match the papering, drapery, or furniture on which it is to be placed. A fire will melt the rubber separating the two wires, and by virtue of the thick coating of tin will solder the two together, thereby closing a circuit and ringing an alarm. The wire may readily be run through any desired parts of the building without being noticeable, and thereby affords a very cheap and simple protector. It has the disadvantage that it requires the direct action of the flame to actuate it, but this is in many cases no great objection and is partially compensated for by the fact that it can readily be run in any desired parts of a room. It has the additional advantage that it can not, like many others, give a false alarm, and there is therefore no objection to connecting it directly with the fire department of a city. It is less than one-eighth of an inch in diameter and is quite flexible; it is sold for about 1 cent per foot, and is said to require only fifteen to eighteen seconds to fuse the contact between the wires. In mounting it, it may be connected to a small push button, by means of which one can at any time assure themselves of the proper working conditions of the whole system.

Burglar alarm.—Messrs. Chubb & Co. (British section, bronze medal) exhibited a burglar alarm attached to a fireproof safe. The apparatus rings an alarm if the door is opened or if the wires are tampered with in any way, either cut or short circuited. The general principle of the circuit is, as usual, that of a Wheatstone bridge, in which the wires at the contact on the door form one of the arms; any disturbance of the balance of the bridge will ring the alarm, and it will continue ringing until stopped at the bell itself. The constant current for the bridge is said to be very small and requires only one cell; the apparatus is said to be independent of variations in the strength of the current of this cell. A galvanometer needle attached to the apparatus shows whether all is in working order on setting the alarm. Although providing for a number of different cases, it does not appear to cover the case of the bell wires or the battery wires being cut; the battery might be put into the safe, but the bell must necessarily be outside. For a description, with a good illustration, see Industries, June 14, 1889.

Railroad signals.—This branch belongs more properly to the subject of railroad engineering, and is therefore not included in this report.

References.—For recording and indicating apparatus, see "Miscellaneous applications," below. See also references at the end of the subject of "bells."

BELLS.

Notwithstanding the large number of exhibits of electric bells and appliances, there was little of special interest. Among those differing from the usual forms of bells was an exhibit of Louis Borel (French section, bronze medal), in which the principle was that the contact breaker did not break the circuit until the armature touched the magnet; that is, until the armature had received the full force of the magnet; in the usual form of vibrator this is not the case, as the circuit is broken as soon as the armature begins to approach the magnet. The advantages claimed, and probably justly, too, are that the force is utilized much more completely, or in other words that a smaller battery will do the same work. The armature does not break the circuit directly as usual, nor is it connected to the hammer; it is pivoted so as to be free to move, and when close to the magnet it strikes, with the full force of its accumlated energy, the pivoted hammer, which latter in moving breaks the circuit; this enables the force of the armature to be used in the position in which this force is a maximum. The external appearance of the bell is also of interest as a complete departure from the usual forms. The whole apparatus is in the form of a large acorn, hanging on a pendant from the ceiling or from an ornamental bracket. The upper part of this acorn is the bell proper; the lower part contains the mechanism, the leads being the suspension.

Bonnet (French section) exhibited a bell having two clappers striking it in different parts and thereby producing two different and distinct sounds or signals; by means of a three-point push button these two can be rung together, producing a third distinct signal.

In the electric trumpet devised by Zigang and exhibited by Bassée-Crosse (French section), the bell was replaced by a small vibrating diaphragm at the base of a small trumpet. The armature of the magnet was directly on the diaphragm, which contained also the interrupter. By means of an adjusting screw the pitch of the note emitted may be altered slightly, thereby enabling it to be distinguished from a second one in the same room. It is said to require less battery power, as the energy required is said to be less. The sound is said to be more decided and penetrating, for which reason it is used largely as a railroad signal.

Another call bell of interest, called the "magnetic bell," is one devised some years ago by Abdank-Abakanowicz, and exhibited by Reichmann (Russian section). Its chief point of interest is that it requires no battery. The current is generated by means of a small alternating-current magneto, consisting simply of a permanent horseshoe magnet and a small coil of fine wire, which is fixed to a stiff flat spring so as to be capable of vibrating to and fro between the poles of this magnet. To generate the current all that is necessary is to snap this spring, which is readily done by means of a convenient handle; the coil will vibrate for a few seconds, generating a momentary current every time it passes between the poles of the magnet. The receiver, or bell, consists simply of an electro-magnet, with a polarized armature, which contains the hammer to strike the bell. There is no interrupter, as the current is an alternating one. The whole is of extremely simple construction and is not likely to get out of order. The sizes are almost unlimited. Bells were exhibited 18 inches in diameter, while others are said to have been constructed 3 feet in diameter. As the electromotive force generated is very high (in the small sizes it is said to be about 75 volts), the bells may be at a very great distance. They are used largely for railroad work, as also for telephone calls. Push buttons and door-bell pulls are arranged so as to snap the spring by the action of pressing the push button or pulling the knob of a door bell.

References.—A few other exhibits closely allied to this subject of calls, bells, and annunciators have been referred to the subjects of "telegraphy" and "telephony," where they more properly belong. See, also, "Miscellaneous applications," below.

ELECTRIC CLOCKS AND TIME DISTRIBUTION.

These exhibits belong more properly to the class "Watches and clocks" (class No. 26), in which most of them were exhibited. They will therefore not be described here.

The following notes regarding some of the exhibits may be of interest here. Reclus (French section) gives the following data regarding the battery power used in his clock. The distributing or master clock is wound up electrically, requiring every half minute a current of 400 milliampères for one-twentieth of a second, which makes a consumption of 57 coulombs per day, or 6 ampère hours per year; the Leclanché cells will, therefore, run it about 3 years. The receivers, which are also run electrically, require 125 milliampères every minute for about 1 second, making 180 coulombs per day, or 18.25 ampere hours per year. He states that a good Leclanché can deliver 350 to 400 coulombs per day without sensible polarization. It is therefore not overworked with 180 coulombs output per day. He gives the total capacity of the cells he uses as 90,000 to 150,000 coulombs, and that therefore the cells will run the receivers about 18 months.

In the Gardiner system of time distribution (United States section, Government exhibit), used by the United States Naval Observatory, a master clock sends a momentary current to line at noon every day which sets the hour, minute, and second hands of the independent, supplemental, or controlled clocks exactly to noon, no matter how much they have varied during the previous twenty-four hours. This is accomplished by an ingenious pin and cam motion on the hands, which is actuated by the current, and which moves all the hands to 12 o'clock and immediately releases them again, each supplemental clock being complete in itself. This correcting attachment may be put onto many clocks already in use, and they can be set by merely connecting them about noontime to the many circuits through which this noon current is sent from Washington. It is in practical operation over lines covering more than 50,000 miles of territory, and is said to be the only system accepted and adopted by the United States Government in all the Department buildings at Washington. It is stated also that time is sent from their lines to Spain via Havana.

For a well-illustrated and detailed description of the well-known Hipp's system of electric clock and time distribution in eastern Switzerland (exhibited in the Swiss section, gold medal) see La Génie Civil, March 24 and 31, 1888.

The "Horatéléphone" exhibited by Salvaing (French section, honorable mention) is intended to replace the expensive tower clock in small hamlets and villages, by a small clock which by electrical transmission will strike the hour and half hour (by repetitions of the hour) on any convenient tower bell in a church tower or public building.

GAS LIGHTING.

The exhibits in this class were not numerous, as such apparatus, so very common in the United States, is used very little in France, owing greatly to the fact that gas is used much less in private houses than it is in the United States. Oil lamps are preferred by many, even by the wealthy.

Some ingenious devices were exhibited by Née and also by Giraud (both French). One of them was for lighting a burner by the act of turning the cock. The apparatus was simple and could be attached to any burner, plain or Argand, between it and the end of the bracket. The turning of the cock lights a small auxiliary flame which is long enough to light the main flame, and which is again turned off when the other is turned on full. The objection is that the gas flame can not be turned down partly without causing a leak from this small flame. Also, that in this as well as in other forms of this device, it is possible, by leaving the cock partly turned, to keep the battery short-circuited, a case which is not possible in the usual American forms. A modification of this was shown, for lighting from a short distance by means of a rubber bulb and small flexible tube, the air pressure from which turned the cock by means of a small piston forming part of the mechanism.

Reference.—For electrical ignition in gas engines see "Miscellaneous applications," below.

DOMESTIC APPARATUS.

Numerous minor devices were exhibited for various purposes, chiefly in private houses, but they were mostly either of the nature of playthings, or of little novelty or importance. One of the most common was a small low resistance battery or accumulator conveniently arranged in a box having a contact key, a small spiral of fine platinum wire and a small wax taper touching the latter. On pressing the key the current heats to redness the coil of platinum which lights the taper. From this a candle or another taper can then be lit. These appear to be used largely in France, judging from the large number of exhibits. This may be due to a great extent to the very high price of matches in France.

MISCELLANEOUS APPLICATIONS OF ELECTRICITY.

Under this heading will be mentioned only those applications in which small currents are required, as distinguished from those in which currents of greater quantity are required, and which therefore belong to the same class as dynamos, lamps, motors, etc., which see for such miscellaneous applications. It will be noticed from the following numerous applications that electricity is coming into use very largely and in very many different ways either as a simple substitute for other means which would require very complicated mechanical apparatus, or as an auxiliary means for doing what could not have been done otherwise.

GAS ENGINES WITH ELECTRICAL IGNITION.

The ignition of the gases in gas and petroleum engines by an electric spark appears to be coming into use more generally, judging from the large proportion of engines exhibited in which this way is preferred to the gas-flame ignition. There were exhibited twenty-one different systems of gas and petroleum engines, counting the various different exhibitors of the Otto engine as one exhibit. Of these, thirteen (or 62 per cent) used electrical ignition, and only eight (or 38 per cent) used the gas-flame ignition.

Historical.—The following abstracts regarding the history of electrical ignition are taken from a paper of Mr. Delamere-Deboutteville, read before the Institution of Mechanical Engineers July 3, 1889. In 1844 John Reynolds used a platinum wire heated by means of a battery. A mechanical contact maker and breaker started and stopped the current at the proper moment. In 1850 Shepherd used an electro-magnetic generator in place of a battery. In 1857 Barsanti and Mattenni used a Bunsen battery, with a de la Rive multiplier, the sparks from which were used. In 1860 Lenoir replaced the de la Rive multiplier by a Rhumkorff induction coil. The primary current passed continually, and the secondary was closed when the spark was required. There was difficulty in timing the spark exactly.

General.—The heated platinum wire is apt to become cooled at the moment of the passage of the gases, and it can not be timed sharply, besides requiring considerable battery power. It therefore seems to be abandoned. All the engines exhibited used the spark. The chief advantages of the spark over the gas flame appear to be its very high temperature, which is of importance, especially when poor gases are used; it is independent of cold or moist air; it reduces the temperature of the valve chest and parts, and thereby facilitates lubrication of those parts and does away with incrustations formed there; in some of the systems it can be very definitely timed, which is claimed to be very important, as there is said to be a considerable difference in the power if the time of ignition varies one-twentieth of a second. The disadvantages of using electricity in place of the gas flame depend upon the particular system used; in general it introduces something with which the ordinary mechanic is not familiar.

Classification.—The systems exhibited are here divided, for convenience, into four classes. All, in common, use electrical ignition only, having no means for gas ignition, showing that they can rely entirely upon the spark. In all but one the spark is made to pass in the cylinder; in the other it is in a special chamber. The insulation of the parts entering the cylinder are variously of porcelain, plaster of Paris, or asbestos, in order to stand the heat and the mechanical pressure of the explosions.

First system.—In the first system a battery, generally two or three large Bunsen or bichromate cells, is used with an ordinary Rhumkorff induction coil having a simple hammer vibrator; the vibrator acts all the time while the engine is running, and the spark of the secondary coil is operated by various means. In all of these the spark passes between two *fixed* points in the cylinder. The advantages of this system over some of the others is that there are no moving parts entering the cylinder; that there are numerous sparks generated instead of a single one, as in some of the others; and that the spark can be well timed. The disadvantage is that the vibrator acts all the time, which is bad for the contacts of the vibrator, and consumes battery power continually.

Details.—In the engine exhibited by E. Roger (French section) the secondary circuit is normally open at a sort of switch outside of the cylinder, which is operated by the moving parts of the engine, and is closed the instant the spark is required for the explosion. When the switch is closed the only break in the secondary circuit is in the cylinder, where the sparks are therefore produced. It is evident that no premature explosions can take place.

In the engines of Louis Charon and those of Solomon Frères and Tenting (French section) the secondary circuit is continually short-circuited outside of the cylinder, except the instant when the spark is required. Premature explosions can not take place unless this short-circuiting switch is exceedingly dirty. They used two large cells.

Those of Thomas Powell (French section) differ essentially from the others, in that the spark passes continually in a spark chamber, which is closed by the slide valve. When ignition is to take place a port in the slide valve makes this spark chamber communicate with the cylinder, thus igniting the gases. The length of the spark is 1.5 millimeters, or about $\frac{1}{16}$ inch. They claim that the instant of ignition can be more accurately and definitely timed by these ports in the slide valve. There is probably more possibility of premature explosions, as in the flame-ignition engines, causing it to "sneeze." They use only one cell of two carbon plates in bichromate solution, the zinc being in sulphuric acid in a porous cup.

Second system.—In the second system a battery and induction coil are used as before, but the primary circuit, instead of the secondary, is closed when the spark is required. The vibrator, therefore, acts only while the primary circuit is closed, thus economizing battery power. It has the same advantages as the first system, except that the spark is not so definitely timed, and is not so sure, as it is necessary that the vibrator starts itself and responds promptly; to do this it must be well adjusted, and its contact must be very clean; it is difficult, if at all possible, to clean it while running.

To this class belong the engines of the Société des Moteurs à Gaz Français, A. F. Noel (French section), and of the Société Anonyme des Moteurs Inexplosibles au Pétrole et au Gaz (Belgian section). In these the primary circuit is operated by a contact piece on the shaft or other moving part, and a brush sliding thereon, usually made adjustable in order to time the spark. The one exhibited by Rouart Frères et Cie (French section) was a double-cylinder engine, and in addition to the above there was a second contact piece on the revolving shaft connected to the secondary circuit, and having two brushes, the object of which was to switch this secondary circuit alternately to each of the two cylinders. They used only two large one-gallon bichromate cells. The frame of the engine was used as a ground-return circuit for both the primary and the secondary currents.

Third system.—In the third system a magneto machine is used to generate the spark without an induction coil. The armature of the magneto, usually a simple Siemens H armature, is kept from revolving by a strong spiral spring. For each explosion it is revolved on its shaft through 90 degrees against this spring and allowed to snap back to its normal position, during which rapid return motion it generates a momentary current. An instant after the armature is released, and at the moment when its current is a maximum, the circuit is broken in the cylinder, producing there a single bright spark. The advantages are that no battery is required, there is no coil with a vibrator to keep in order, and it is always ready to start; as the high rate of rotation necessary to generate the current is produced by a snap movement, no great speed of the engine is required at starting, as would be the case if a dynamo was used in place of a magneto. A disadvantage is that only one spark is produced in place of a number of them as in the other systems, but as it is a much more powerful spark, and quite positive, this does not appear to be an objection. In this system there must be moving parts entering the cylinder to break the current there.

The engines of Gotendorf & Co. and of E. Delahaye (French section) were of this class. In the latter the exact time of the spark may be adjusted by a cam movement. The engine of W. C. Horne (British section) also belongs to this class. It differs from the other two in that the H armature is normally in the stable position into which the magnets would pull it, the spring assisting it to return to this position, while in the other two the normal position is the unstable position, in which it is held against the magnetic pull by the spring, which must, therefore, necessarily be much stronger. The spark is produced between two steel springs in the cylinder, operated by means of a rod passing through a stuffing-box. This rod has a rotary notion instead of a longitudinal one, thereby facilitating the construction of the fireproof stuffing-box.

Fourth system.—In the fourth system a dynamo or magneto is turning all the time, generating the current, which is broken in the cylinder directly without a Ruhmkorff coil. The disadvantages of this system are that in starting the engine sufficient speed must be produced by hand before the dynamo will generate sufficient current to produce a spark.

In the engine of E. Durand (French section) a small, simple magneto is used, generating an alternating current. Both wires are insulated; that is, the frame of the engine is not in circuit. The circuit is broken in the cylinder by a revolving rod, as in the engine of Horne. No self-induction coil is used.

In the Baldwin Gas Engine (United States section) the current is generated by a small shunt-wound dynamo of about one-eighth horse power. It is driven directly from the fly wheel by a friction pulley, the pressure being produced by its own weight. There are two friction pulleys of different sizes. The smaller one, for high speed, is used only for starting. There is a self-induction or spark coil in circuit, and the circuit is closed except when the spark is required. The breaking of the circuit is operated by an insulated pin passing into the cylinder and having a longitudinal motion. It is difficult in this arrangement to keep the contacts in the cylinder clean, especially as the tendency of this particular construction is to destroy its own contact.

MINE BLASTING.

There are two classes of electrical mine blasters—the low-tension class or those in which the ignition is caused by a heated wire, and the high-tension class, in which it is caused by a spark. A special commission appointed by the French Government in 1888 to examine the matter of mine blasting reported that there were important objections to the high-tension caps, and that they recommend the use of those of low tension. The chief objections to those of high tension are the following: The impossibility of exploding the caps unless the leads are perfectly insulated, the difficulty of making them all alike, and the danger of igniting the fire damp should there be a leak from the wires.

Among the exhibits of the low-tension class was one of Manet (French section). The chief advantages claimed are the simple and solid construction of the caps, their cheapness, and the fact that they are all absolutely the same by virtue of their construction, which is entirely by machine. The caps are of a glass tube containing the chlorate of potash powder (not gun cotton), and closed by a wooden plug through which pass two metallic pins, to the inside ends of which is soldered a fine platinum wire 0.377 inch long and one-twentieth of a millimeter (0.00197 inch) diameter; the leads are connected to their pins; the resistance of a cap is 3 ohms; they appear to require from one-third to two-thirds of an ampère. The exploder is a small hand dynamo weighing only 22 pounds; the size is only about 10 by 8 by 8 inches. It has an electromotive force of about 80 volts. It is a self-exciting series machine, and is turned by a crank and a train of four gear wheels. An automatic switch attached to the dynamo will switch the current into the external circuit the moment it has reached the proper strength. It is able to explode eighty fuses without a line resistance, or twenty with a line resistance of 4 ohms. The line resistance is proportioned so that the total external resistance is the same, namely, 64 ohms for any number of fuses up to twenty. The diameter of the leads must therefore be chosen in accordance with the distances, which is a feature not without its objections. The advantages of the dynamo are that it is independent of the state of the atmosphere, and its current is always exactly the same. The dynamo includes a bell-testing appliance, by means of which the continuity of the circuit may be tested before proceeding with the explosion.

Burgin (Swiss section, bronze medal) exhibited a small and very conveniently arranged hand dynamo for the same purpose, with the addition of a switch by means of which either a high-tension spark or a low-tension current can be produced by different internal connections of the dynamo. The dynamo is automatically switched onto the circuit at the proper moment by a magnet in the main circuit. A cap was exploded in the presence of the writer through the joint resistance of four persons in series joining hands.

Breguet, Ducretet, and others exhibited mine exploders of the old form of a steel magnet with soft-iron pole pieces surrounded by coils, the spark being produced by a sudden tearing off of the armature produced by a blow with the hand. Scola & Ruggieri (French section) exhibited one of these with the additional improvement that the soft-iron cores were laminated, by which the induction and therefore the capacity of the apparatus was increased.

ELECTRIC ORGANS.

Historical.—The first application of electricity to musical instruments having a keyboard is said to have been conceived more than one hundred years ago by a priest from Nivernais, named Jean Baptiste Laborde, but how it was to be applied the record unfortunately does not state; it was, presumably, a mere vague prophecy. The real history appears to have begun in 1867-'68, when an Englishman named Barker, aided by a barrister named Peschard, constructed the first electric organ in the church of St. Augustin at Paris. The principle appears to have been simply to open the valves of the organ pipes by electro-magnets the circuits of which were closed by contacts at the keyboard. This did not prove very satisfactory, owing to the large battery power required, not only in the number of cells, but also in their capacity.

To overcome this important objection Messrs. Schmoele & Mols, of Philadelphia, devised an ingenious relay system, called the electro-pneumatic system, in which the function of the electro-magnets was not to open the valves themselves but merely to open a small aperture under the valves, which admitted the compressed air used to blow the organ, which in turn opened the valve; thus the force required by the magnets was very small, the actual work of opening the valves and moving the mechanism for the different stops being done by the compressed air with which every organ is already supplied.

General.—In general in an electric organ there is a contact connected with each key and stop of the keyboard, and a wire for each leads the current to the respective pipe or stop mechanism and actuates electro-magnets there, which in turn operate directly or indirectly the pipes and stop mechanism. The advantages of electric organs over those operated by purely mechanical means are as follows: The only connection between the keyboard and the pipes being by means of electric conductors, the keyboard and the pipes may be placed any desired distance apart, and either of them may be placed in any convenient part of the church or building, irrespective of where the other is placed; the same keyboard may also be used for several different organs, separately or together, by means of a simple switch putting the battery on either one or the other organ or both together; or there may be several keyboards for the same organ; the keyboard may be moved about, being connected merely by a flexible cable. This electric conductor takes the place of and dispenses with all the complicated levers, pins, wires, and angle pieces, which are otherwise necessary to connect the keyboard with the pipes and which, being very complicated, are apt to get out of order and to be affected by moisture, dryness, and dust, causing variation in their action. The force required by the player in depressing the keys and moving the stops, being merely to close a small contact, is practically nothing. The keyboards, stops, etc., can be brought into as small a compass as desired, thereby making it easier for the player.

Organ exhibited.—There was only one electric organ at the exhibition. It was exhibited by Messrs. Merklin & Co. (French section), and made in accordance with the patents of the American inventors, Messrs. Schmoele & Mols. The organ proper was in two parts, placed at the two ends of the upper gallery, while the single keyboard was in the center of the main floor below. The system was that called the electro-pneumatic system mentioned above.

Valve mechanism.—The mechanism for opening the valves and for working the mechanism of the stops may be briefly described as follows: The valve is attached to the movable part of what might be termed a small pair of bellows directly below it, and in the same compressed air chamber. The compressed air normally presses on both the inside and outside of this bellows, and, therefore, does not actuate it. The action of the electric magnet is simply to open a small aperture of this bellows, allowing the inside to communicate with the open air; the pressure of the compressed air on the outside of the bellows consequently closes it, and being attached to the valve of the organ pipe, it pulls it open, forming with it a sort of balanced valve. The force required by the electro-magnet is therefore very small; the armature weighs only a gram (15 grains) and its movement is only 1 millimeter ($\frac{1}{25}$ of an inch). All the mechanism of the stops, no matter how heavy, is actuated in the same way by a sort of bellows, larger in proportion to the work they have to do, and controlled electrically by a very small magnet.

Contacts.—As the current used is very small the contacts may be made very simply. They consist of small, flat springs of German silver, which are attached to the lever of the key, and slide over a fixed contact piece, thereby cleaning themselves each time they move. In the older systems of electric organs in which the valves were opened directly by the magnet, the currents necessary were so great that the contacts had to be made with mercury cups and wires dipping into them.

Battery.—Five Lalande & Chaperon cells are said to be sufficient for a large organ and will not need attention more than once in several years. In one of their organs at Lyons four of these cells were used; the box containing them was not opened for three years, during which time they did not fail once. The cost of recharging them is very slight, amounting, it is claimed, to only 40 to 60 cents a year.

Cost.—The cost of these electrical organs is stated to be the same as that of mechanically operated ones.

MELOGRAPH AND MELOTROPE.

Carpentier (French section, gold medal, for this exhibit alone) exhibited in the class of musical instruments a set of instruments called melograph and melotrope. The object of the former is to make an accurate and permanent record of what is being played on a special piano. The object of the melotrope is to mechanically reproduce this music on any other piano from the record of the melograph or from duplicates of the same. The melograph operates electrically as follows: A contact is secured to each key of a piano; these are connected by wires to the melograph proper, which consists of a corresponding number of electro-magnets, operating a set of ink-writers, which record a series of parallel broken lines. The relative positions of the lines of this record, therefore, indicate the pitch of the notes, and the lengths of the lines indicate the time or length of the note. For a range of three octaves, or thirty-seven notes, the record is a band of paper, about 4 to 5 inches wide, having room for thirty-seven parallel lines. This band of paper is made to pass through the melograph or ink-writer at an absolutely constant rate of speed by means of a small electric motor and an ingenious mechanical regulator. From this melograph record any number of duplicates are then made, in the form of a band of stiff, tough paper, with rectangular holes punched through them, corresponding in position and length to the marks on the original record. These duplicates are sold in the market and are ready for use in the melotrope. The latter is a small rectangular box, placed over the keyboard of any piano; it is operated by a crank and fly wheel and strikes the keys by means of pins. The perforated band of paper is passed in at one end and out at the other. Its operation is purely mechanical, and therefore does not come within the scope of the present report. For a very good and fully illustrated description of the whole set of apparatus, see La Lumiere Electrique, Vol. XXVI, 1887, No. 53, p. 651.

AUTOMATIC WEIGHING MACHINE.

Among the weighing machines was one called the Spelgrove electric weighing machine, exibited by Messrs. W. & T. Avery (British section), in which the operation of adjusting the sliding weights on the steelyard or beam was performed automatically by electrical means. The object of this machine is to combine the accuracy, reliability, and great capacity of the lever or beam scale with the self-indicating advantages of the spring balance. All that the operator needs to do is to place the objects to be weighed on the platform of the scales and read off the numbers on the dials when the steelyard has come to rest.

As the construction of the automatic apparatus for adjusting the weights is very complicated and intricate, perhaps more so than is necessary, nothing more than a general description of the principles of this operation will be given here. In Engineering, June 21, 1889, there are some good working drawings of one of these scales, differing only slightly from the one exhibited; the description, however, is not very clear.

The general construction of the scale is that of the usual platform beam scales, having two sliding weights, one small and the other large. The whole of the operating mechanism is on the beam itself. This is an essential feature. At the free end of the beam, in place of the usual stops for limiting its movements, are two electrical contacts, one above and one below the beam; closing the upper one causes the weights to advance on the beam, the lower one causes them to recede. One or the other of these contacts will therefore always be closed as long as equilibrium has not been reached, and the mechanism will not come to rest, even if it has made a mistake, until the beam rests between the contacts, when equilibrium has been reached. In a scale for 500 kilograms the small weight will adjust itself in steps of one-half kilogram up to 10 kilograms, and the large weight in steps of 10 kilograms up to 500. The adjusting weights are pushed forward by a small fixed electric motor on the beam. They are brought back by springs. In placing the goods to be weighed, for instance 86.5 kilograms, on the platform, the beam will move up and close the upper contact. This starts the motor, which pushes the small weight out to the extreme end, registering 9.5 kilograms. On arriving at the end of the beam it closes another contact which causes the large weight to be pushed out in steps of 10 kilograms, until overbalance is reached, which in this case would be at 80, therefore registering altogether 89.5 kilograms. This causes the beam to tilt and to close the lower contact. This in turn relieves the small weight, which moves back by a step-by-step escapement until exact balance is reached at 6.5 when the beam will rise, open the circuit, and rest between the two contacts. On taking off the load, the beam falls and closes the lower contact, which releases the small weight, which, when it arrives at zero, closes a contact there that releases the large weight. It will be seen from this, that should the machine make a mistake by moving the large weight too far, the automatic action will be to bring both back to zero and make them start over again from the beginning. The weights can not come to rest until equilibrium has been attained. A weighing is stated to require from six to twelve seconds, while two to three seconds are required for the return of the weights to zero. For ordinary intermittent work, a battery of large Leclanché cells is said to be sufficient.

A number of difficulties in an electric scale of this sort are overcome by the ingenious idea of making the small weight move first, to the extreme end of the beam, then moving the large weight out to overbalance, and finally moving the small one backwards to the required position. This operation is the reverse of the natural one in adjusting by hand.

Scales weighing up to 1,000 pounds adjust to a pound, that is, to one-tenth of 1 per cent. Those for 40,000 pounds adjust to 8 pounds, that is, to two-tenths of 1 per cent.

While the machine in its present form is probably too complicated to come into use very largely, the principles are good and will doubtless admit of a simpler construction.

MACHINE FOR AUTOMATICALLY WEIGHING OFF AN EXACT AMOUNT OF YARN.

The object of the machine is to weigh off rapidly and with precision an exact predetermined amount of yarn and to wind it into balls or otherwise, in the form in which it is to be sold. It was exhibited by Mouchère, in the French section, in Class 54 (Appliances and Methods of Spinning and Rope Making).

It consists essentially of a pair of scales, an apparatus for feeding the yarn on to the scale pan, an apparatus for stopping this feed at the proper time, and a machine for winding the measured amount of yarn into a ball or any other desired form.

The yarn is placed in skeins, as it comes from the spinning machine, upon two reels or rollers above the machine. The thread passes loosely between a pair of smooth jaws like those of a vise; thence between a roller and an idle pulley resting on it, and finally into a light cylindrical box of tin, which is the scale pan of the weighing scales.

By means of a chain gearing and a large wheel this roller is turned rapidly (by hand or by other power) and pulls the thread of yarn off the skein and into the box as long as the idle pulley rests against the roller. The tin box into which the yarn is thus fed is on one arm of a pair of scales, on the other arm of which is placed the required weight. On the weighted end of the scales there is a wire dipping into a mercury cup, thereby keeping an electrical circuit, from a battery or small dynamo, closed, as long as there is not the required amount of yarn on the pan. In this circuit there is a powerful electro-magnet, the armature of which is secured by levers to the idle pulley and vise jaws described above. As soon as the weight of the yarn, which is being fed on to the scale pan, is sufficient to counterbalance the weight on the other arm of the scales, the tilting of the scale beam opens the electric circuit at the mercury cup and thereby releases the armature of the magnet which in turn raises the idle pulley from the feed roller, thereby stops the feed, and closes the vise jaws, which then hold the thread securely at the required point. An empty scale is then put in place of the one which is full; and while the second quantity is thus being weighed off the first is simultaneously wound into a ball by a simple winding apparatus attached to and operated by the same machine.

The success of the machine seems to be due to the fact that the weighing and the winding are not one and the same, but are two successive operations. The precision with which the yarn can thus be weighed depends evidently only on the sensitiveness of the balance used. Instead of opening a circuit when the required weight is reached, the apparatus might be arranged to close a circuit, thus economizing current. But the latter would have the disadvantage that should the current, from any cause, fail it would not render itself evident, as in the reverse arrangement, in which, if the current fails, it stops the feed.

KNITTING MACHINE IN WHICH THE DESIGN IS PRODUCED BY ELECTRICAL MEANS.

Among the weaving and knitting machines was one exhibited by Emmanuel Buxtorf (French section), in which the design, in two colors, was produced by a very simple electrical contrivance attached to the ordinary machines. It is a very good example of a case in which a very simple electrical attachment to a machine will perform an operation which would require a very complicated apparatus to do mechanically, if it could be done at all.

The machine is for making material like that for jerseys, hosiery, etc., which is made in the form of a cylinder, and is woven of a single thread, which is knitted on by a continuous circular movement of the knitting mechanism similarly to the way in which a stocking is knit. The design of two colors is produced by using two threads of the two colors side by side, in [illegible] of the single one, being therefore practically the equivalent of a single thread the two sides of which are colored differently. These are led to the needles side by side, so that one of them hides the other, therefore making one side of the material one color and the other side the other color. By merely interchanging the relative position of these two threads a design of two colors is produced, the one on the back being the negative of the design of the face.

This interchanging of these two threads is effected by means of two light guides, which are moved by an armature of a small electro-magnet, which is attracted or released according as one or the other colored thread is to form the face of the material. The current for the magnet is made or broken by a contact-pin sliding over the surface of a small rotating brass cylinder on which the design has been painted with thick shellac or other insulating compound. Whenever the pin passes over the shellac the circuit is broken. This design cylinder is rotating in exact correspondence with the cylinder of material which is being woven, and also has a corresponding axial motion, so that the position of the contact-pin on the design cylinder corresponds exactly to the place on the material where the thread is being woven into it. The exact place where the threads are to be interchanged corresponds, therefore, to the place where the current is made or broken by the design of shellac on the brass cylinder. By rotating this design cylinder two or three times as fast, the design will be produced in two or three places, respectively, on the material; by increasing or diminishing the axial motion of the design cylinder the design will be shortened or elongated, respectively, on the material, producing quite different effects.

The original design is evidently not limited in any way as to its shape, outline, irregularity, or simplicity. Owing to the nature of the weaving, the color on the back of the material shows through lightly on the face, making the face slightly less definite and prominent.

The operation of weaving a colored thread into such material was done before by mechanical means, but it was limited to geometric patterns, and the mode of weaving in the colored thread rendered the material inelastic.

LOOM ARRESTER.

Among the electrical devices for automatically stopping a spinning and weaving machine when a thread is broken, or in general when any fault arises in the process of the weaving, were a number of devices exhibited by Radiguet, (French section, class 55). The action is, in general, that any fault or failure in the weaving will cause a contact to be closed which actuates a small, light magnet. The action of this magnet is simply to trip a small lever, which therefore requires only a very small current. The releasing of such lever puts into action a more powerful mechanism, which shifts the belt and stops the machine. By this means a very small current is sufficient to actuate the necessarily heavy mechanisms. The apparatus furthermore cuts the current off as soon as the mechanism has operated, to avoid waste of current. It is furthermore so arranged that the workman can not start the machine until the fault is repaired. The inventor prefers to employ metallic circuits throughout, instead of using the frame as a return circuit. He seems to have been one of the earliest workers in this field, having begun in 1865. He claims that over 8,000 looms are already fitted with these devices.

TRICYCLE.

Millet (French section) exhibited a tricycle of peculiar construction, with spring spokes and flexible rim, which was operated by a sort of gas motor, the gas being ignited by electricity from an induction-coil and a small primary battery. There was nothing novel or important about the electrical portion of the apparatus.

MACHINE FOR VOTING.

Debayeux (French section, honorable mention) exhibited a voting machine. The voter moves a pointer opposite to one of a vertical list of names and pulls a lever. Nothing more could be ascertained about the exhibit.

ELECTRIC LOCK.

Piret and also Lémonon (both French) exhibited an electric lock for a door, which enables the door to be opened from a distant point by a push-button. It is an attachment to replace the metallic part on the jamb of a door, into which the bolt of the lock passes, and can therefore be adapted to any existing lock without changing the lock itself. An electro-magnet trips a lever which opens the side of this catch, enabling the end of the bolt to pass out through the side unobstructed without withdrawing the bolt of the lock. A spring pushes the door open slightly. It is for use in public buildings, as for instance for the exit doors of factories or prisons, the fire exits for theaters, etc. Also for the front door of houses divided into flats, etc.

RECORDING AND INDICATING APPARATUS.

Numerous electrical devices were shown for automatically registering or indicating at a distant station various meteorolgical observations, such as temperature, direction of wind, rainfall, etc.; also the level of water in reservoirs, the rise and fall of tides, etc. Such apparatus belongs more properly to other classes, such as meteorology, instruments of precision, engineering, etc., for which see the reports of other experts.

IV.—ELECTRO-CHEMISTRY.

ELECTROPLATING AND GALVANOPLASTICS.

General.—The deposition of thin coatings of metal from their solutions, by electrolysis, practiced on a commercial scale more than thirty years ago, is shown by the exhibits to have reached a very high state of perfection. The improvements made more recently have been chiefly to improve the adherency of the coating, to vary the nature and appearance of the coating, to increase the list of the metals and alloys which may be so deposited and on which adherent depositions can be made, to coat insulating materials, to color with the oxides of metals, etchings, etc. Among those metals exhibited which formerly presented difficulties are platinum, zinc, tin, iron, cobalt, arsenic, black oxide of iron, brass and bronze, as metals to be deposited, and zinc as metal to be coated.

Galvanoplastics, or the deposition of thick, self-sustaining masses of metal, is coming into use very largely on a commercial scale, chiefly for the manufacture and reproduction of ornamental, artistic, or historically interesting metal goods; important among these are the productions of busts, statues, solid silver goods, and reproductions of antiquities, in their original metals, even iron, such as iron armors.

Electro-metallurgical processes, for reducing the metals from their ores, are also being developed on a commercial scale. Among the exhibits in this class were three electrical processes for obtaining aluminum, one for zinc, and one for obtaining pure iron from iron scrap. Other electrical processes belonging to this class included one for making sulphate of copper, one for bleaching, and one for purifying water and liquors.

Exhibits by countries.—With the exception of two of the metallurgical processes, all the exhibits were in the French section. While they were probably not as complete as might be desired to show the full state of the art, yet they were very interesting and showed considerable development.

DETAILED DESCRIPTION.

The following detailed descriptions are confined to a summary of some of the more interesting exhibits. As the processes are in almost all cases kept secret, it leaves little to be described here, more than a mere mention of the principal exhibits.

Christofle.—By far the finest exhibit of electroplating and galvanoplastics was that of Messrs. Christofle & Co. (French section), who were one of the few in the whole electrical section who received the high award of grand prize. They are the oldest and est house of the kind in France, if not in the world. Th carried the art to a state of perfection which few if any others have reached.

Their exhibit of reproductions of works of art and antiquities in their true colors and metals, by electro-chemical means, was one of the most interesting portions of their exhibition and appears to be their specialty. Among their exhibits of reproductions were life-size statues of copper; others of bronze and other metals and alloys; solid silver ornaments and articles; old steel armors reproduced in iron directly; and many other articles, from the most delicate to large and massive pieces. Among the exhibits of electroplating were samples plated with almost all known stable metals and a number of alloys of shades of many different tints. Samples of etching, oxidizing, coloring by oxidizing, aging, and other effects were also shown. Another process of interest is that of superficially bronzing a copper statue by plating it with a coating of zinc or tin and then heating it, whereby the zinc or tin will alloy with the copper, forming brass or bronze on the surface.

Their process of making a hollow reproduction in copper of a bust, in one piece—that is, without a joint—was shown in detail. The mold or cast of the original is made of gutta-percha and forms the retaining vessel for the solution; the anode is a thin foil bent so as to be roughly the form of the inside, but considerably smaller. This anode is of lead, not of copper, the metal which is deposited being that obtained from the liquid only, which must therefore be renewed. In the silversmith department they had a beautiful exhibit of very artistic solid silverware made electro-chemically. Such processes of making ornamental solid silverware have a number of advantages over shaping by hand, giving exact reproductions of the original and being quite rapid and cheap. They have made many copies or facsimiles of historical antiquities from the originals, and with their true appearances, for museums and art schools.

Other exhibitors.—There were besides Christofle a number of other exhibitors of articles of this class of more or less importance.

C. M. Rivaud (French section, bronze medal) had a fine exhibit of ornamental work and of depositions of the precious metals on insulating substances, such as glass ornaments, agate handles, vases, etc., on which the metal, silver for instance, was deposited as a thick layer and afterwards carved away in designs, leaving the metal as a decoration on the glass, it being secured to the glass by virtue of its shape, as a band, for instance.

L. Magniny (French section) exhibited a large number of articles of vegetable, animal, and other insulating substances, electroplated for preserving them or for ornamentation. Among these were natural flowers, leaves, mosses, grasses, insects, laces, ribbons, hats, plaster statues, wooden furniture, wicker baskets, and many other interesting and more or less useful articles. Some of these materials are very difficult to plate, not only on account of getting the first metallic coating on the insulating substances, but also because many of them are apt to swell and warp when in the bath.

G. Bajou (French section, silver medal) had a fine exhibit of aristic decorative work, including depositions of different colors of alloys, oxidations, frosted finish, etching, inlaid work of different colored metals and enamels.

Claude Lionnet (French section, silver medal) exhibited a large copper statue, once and a half life size, made by electro-chemical deposition; also negatives, in the form of rollers, of ornamental leathers for pressing imitation leathers.

A. Gaiffe (French section, silver medal) exhibited articles electroplated with cobalt, nickel, old cobalt, and old nickel. The cobalt resembles very much the more usual nickel, but is said to have some other properties. The old nickel and old cobalt finish presents a very fine appearance.

J. Pérille (French section, silver medal) exhibited nickel-plating on iron and steel direct by a special process. He uses anodes of nickel perforated with numerous large holes, whereby it is claimed the anode is dissolved better.

Iron oxide plating.—Among the novelties which may be of considerable importance is a process exhibited by A. de Meritens & Co. (French section) for electroplating with black oxide of iron, on iron and steel goods, such as rifles, revolvers, and many other articles. It forms a very hard, black, glossy coating, which, being already oxide of iron, does not rust, and forms an excellent and ornamental coating. The promised description of the process was not received by the writer; it is probably a deposition and not an oxidizing at the expense of the metal, and it is said to be a rapid process. From a theoretical standpoint it is a far better coating for iron than nickel-plating is, as the latter, by its electro-chemical affinity, increases the tendency to rust should the iron be slightly exposed.

Plating without current.—A. A. L. Levy (French section) exhibited articles, such as steel pens, beads, buckles, and other small, cheap metal goods, nickel-plated directly by simple immersion in a hot nickel solution without an electric current. The process is exceedingly simple and rapid, and the coating of nickel, though necessarily very thin, is bright and tenacious, and requires no burnishing.

Plated zinc.—Henry & Co. (French section, silver medal) exhibited articles in which various metals and alloys were deposited on zinc directly, which was said to have been difficult to do formerly.

Accessories.—Delval & Pascalis (French section), who are the successors of Roseleur, who is well known for his work in electrochemistry, had a large and fine exhibit of goods for electroplaters. Among other accessories was an apparatus in the form of a pair of balances, by means of which spoons, forks, etc., were suspended in the silver bath, and which opened the circuit automatically when the required weight of silver had been deposited. Another apparatus of interest was a copperplating bath, for armatures, which constituted its own battery. It consisted of a bath of sulphate of copper, in which was placed a porous cup containing a bar of zinc in dilute sulphuric acid. The article to be plated was suspended in the copper bath and connected to the zinc; this forms a short-circuited battery, the current of which deposits copper on the article immersed.

MISCELLANEOUS.

COLORING ELECTRICALLY.

Frederic Weil (French section, gold medal) claims to be one of the earliest to have copperplated iron and steel directly on a commercial scale and to electroplate with other metals. He claims to have been one of the first to have used the dynamo in electroplating. His processes are, however, mostly old and already well known. His exhibit was chiefly of articles electroplated with the lower oxides of copper, producing very brilliant colors, chiefly blue, green, red, and yellow. The colors are bright and clear, the process being used chiefly for ornamentation. Articles of any metal or alloy, even iron and steel, may be thus colored directly and very rapidly at ordinary temperatures and in a single bath. Any one color or a variety of colors on the same piece can be produced at will. It is stated that the coating is not exceedingly thin, as is often supposed, and as is the case with the lead-oxide coloring. This may be shown by the fact that if an article thus coated by his process is treated with nascent hydrogen the coating is converted into metallic copper, which has the true color of copper, and can not, therefore, be very thin.

REPRODUCTION OF ENGRAVINGS.

P. E. Placet (French section, silver medal) exhibited what may become an important advance in making plates for printing from pictures, photographs, engravings, etchings, etc. It is a direct process, reproducing all the so-called "half-tints" of photographs, and requiring absolutely no engraving or "touching up" by hand. The process is, to a great extent, secret, but in general the illustration is photographed on a gelatine plate, which is then exposed to the action of light and other similar treatment (etching, we believe), which leaves it with the illustration raised or depressed. On this is then deposited electrically a negative of a thick coating of copper, from which may be printed directly. The prints shown were very beautiful reproductions, and were remarkably perfect in the minutest and most delicate details. The process is termed gravure hiliographique.

ELECTRICAL PRODUCTION OF SULPHATE OF COPPER.

An interesting process, for which great expectations are held, is one exhibited by Messrs. Perreur-Lloyd et Fils (French section, bronze medal), for the manufacture of sulphate of copper by an electrical process in which electricity is produced as a by-product and may be stored and sold. The process is simply a battery in which metallic copper and sulphuric acid are consumed in discharging, forming copper sulphate as a residue. The cell consists of metallic copper in sulphuric acid, forming the negative pole plate, not the positive as usual; the positive pole plate is a plate of carbon in a porous cup containing nitric acid. On discharging the cell the action is as follows: The copper is dissolved, forming copper sulphate; the nitric acid is reduced to nitrous oxide (NO) which is set free as a gas; in order to regain this nitric acid the gas is led through chambers containing fragments of coke and filled with steam and hot air, by which it is again oxidized to nitric acid, which is then used over again. Theoretically, therefore, all that is consumed is copper, sulphuric acid, steam, air, and some heat, while the products gained are sulphate of copper and electricity. But in practice there will probably be other losses. The quantity of electricty developed is, however, comparatively great; for instance, for every pound of copper dissolved there are 385 ampère hours of electricity generated; the electromotive force is said to be 1 volt, and the useful difference of potential may then be about 0.5 volt, at which rate 192 watt hours are generated for every pound of copper dissolved, which corresponds to 0.388 effective horse-power hour per pound of copper, or about 2.6 pounds per effective horse-power hour, or about like coal used for a steam engine. Owing to the low voltage, however, it requires a large number of cells to develop a sufficiently high voltage to be used directly. It is intended probably for charging accumulators in multiple arc, but even then about five cells would be necessary for charging a single set of accumulators all in multiple arc. The retaining cells are made of lava, being cut out of a solid block, which is said to be necessary, as the cells must be heated to about 160° F. and must stand the action of the hot acids at this temperature. It is claimed that the process is much cheaper than the present method of making sulphate of copper. It appears to have been started only quite recently on a commercial scale.

BLEACHING.

The Hermite electric bleaching process was exhibited by Patterson & Cooper (British section), and by Darblay Père et Fils, paper makers (French section). The process consists essentially of electrolyzing a solution of chloride of magnesium, which, by direct decomposition and attending chemical reaction, produces at the positive electrode an oxide of chlorine which remains in solution in the liquid, forming, it is said, hypochloric acid, which is a powerful bleaching agent; hydrogen is liberated at the negative pole. This liquid is then used to bleach the materials, which reaction simply reduces this hypochloric acid; there is, therefore, no consumption of the chemicals and the same liquid may be used over again repeatedly. The process is a continuous one; the 5 per cent solution of chloride of magnesium is passed through the electrolytic bath continuously; from there it passes through the bleaching bath, from which it is then pumped back into the electrolytic bath. The only loss is the liquid which is retained mechanically by the bleached material, and which is said to amount to from 6 to 10 per cent in twenty-four hours. The electrolytic bath consists of a galvanized iron tank having a perforated supply pipe at the bottom and an overflow pipe for the electrolyzed liquid at the top. In this tank there are a large number of parallel plates, alternately positive and negative. The former are made of thin sheets of platinum in frames of hard rubber to stiffen them; the negatives are round disks of zinc, which are kept revolving slowly and have scrapers attached to clean any deposits which may form on them; these zinc plates, being the negative poles where the hydrogen is liberated, are of course not dissolved. The current used for each bath is from 1,000 to 1,200 ampères, and the potential from 6 to 7 volts, requiring, therefore, about 10 to 12 horse power. The makers guarantee to bleach as much per twenty-four hours with one apparatus as can be done with 100 kilograms (220 pounds) of chloride of calcium. In a published estimate of the relative costs of the old and new method, it is stated that to do the same bleaching as with 1,000 kilograms (2,200 pounds) of chloride of calcium at 230 francs ($44.50) requires power and involves a loss of liquid corresponding together to 102 francs (about $20), making the total cost of the latter less than one-half; this does not, however, include interest and amortization. It is used for a number of purposes, chiefly, it appears, for paper bleaching; it is stated to be capable of bleaching materials which can not be bleached by the ordinary process, as jute, for instance. It is already in use in a number of establishments among which are several in Boston. Very good and well illustrated articles on this process may be found in La Lumière Electrique, Vol. XVIII, 1885, Nos. 48 and 52; also Vol. XXXI, 1889, No. 4; also Revue Internationale de l'Électricite, 1889, Vol. VIII, No. 88, p. 144.

TREATMENT OF LIQUORS.

In the exhibit of A. de Meritens & Co. (French section) there was shown an apparatus for treating water, wines, beers, and other liquors with an alternating current, for the purpose of purifying them by destroying all living organic matter contained therein. It consisted of a row of vertical tubes connected at their tops and bottoms in such a way that the liquid enters at the first and flows through each in succession. In these tubes are numerous perforated plates an inch or two apart, which are alternately connected as positive and negative electrodes. These are attached to an alternating-current machine. The alternating current, therefore, traverses the liquid repeatedly while the liquid is flowing through these tubes. It is claimed that this treatment will destroy all living organic matter and that the liquid thus treated will not spoil. Two dishes were shown in which some liquor before and after treatment had been allowed to evaporate to dryness. In the former there was quite a large quantity of mold, and in the latter merely a stable sediment of a fine powder.

ELECTRO-METALLURGY.

In electro-metallurgy there were the following exhibits: Létrange & Co. (French section) for obtaining zinc; Bernard Frères (French section) for aluminium by the Minet process; Société Anonyme pour l'Industrie a l'Aluminium (Swiss section); Cowles process for aluminium (United States section): Placet (French section) for refining iron by electro deposition from its solution. The latter operation, the inventor claims, can be done for 1.3 cents per pound; he suggests using such iron for the manufacture of steel by fusion with cast-iron, and for other purposes in which pure iron is required. As all these metallurgical processes belong more properly to the department of metallurgy rather than to electricity, the reader is referred to the report on that section.

PRIMARY BATTERIES.

GENERAL.

Among the very many exhibits in this class were a number of improvements and modifications which were of interest and showed some, though not very great progress. The field being already so thoroughly studied, leaves little room for any very great progress; that shown was mainly in details of construction and in slight, though not unimportant, improvements in the elements of the cells.

The exhibits of powerful batteries showed that electric lighting from primary batteries is not only possible but also practicable; but even at its best it must still be considered a luxury on account of the expense, though if all of the facts and figures given by one of the exhibitors are correct, it has been reduced to the very low cost of one-tenth of a cent per candle per hour, for labor and for material consumed; or two-tenths of a cent per candle hour, including everything. Although this is still between three and four times the cost of gas, yet it makes electric lighting by such means practicable for domestic purposes.

The very thorough researches of Renard are of some interest, resulting in his obtaining what is undoubtedly the lightest battery made. Most of the improvements in batteries were in the details of construction; the only one differing essentially from the old well-known types is the Lalande and Chaperon. In the Leclanché type the tendency appears to be to diminish their resistance, to cheapen the construction, and to diminish the attendance required by them; in the latter direction the so-called dry cells are among the chief improvements. The Daniell cell was conspicuous by the absence of any improvements; with the exception of Callaud's well-known improvement of employing gravity to separate the solutions, it appears to have originated as an almost perfect cell.

Processes for purifying zinc, and for the utilization of the residues of batteries are also being developed. One of the interesting novelties was a battery in which the electricity is a by-product, the object sought for being the residue, namely, sulphate of copper.

Conspicuous by their absence were the inventors so often met, who claim to obtain more energy from their batteries than is possible under theoretically perfect conditions. This alone is a proof of progress.

Exhibits by countries.—The exhibits of primary batteries were almost exclusively in the French section, the only exception of note being by one English exhibitor.

Classification.—Owing to the diversity of applications of the different cells no classification will be attempted here, other than that those usually intended for great power will be described first and those for small currents last. Such a classification is, necessarily, only a very general one. Those of the first group are almost exclusively improvements and modifications of the bichromate of potash type of cell, and the latter of the Leclanché type.

BICHROMATE OF POTASH CELLS AND THEIR MODIFICATIONS.

The Gendron cell (French section, bronze medal) is a zinc-carbon couple, with porous cup. The construction presents some points of interest, the object being to obtain great surface of electrodes, small distance between the plates, small quantities of liquid, renewed continually and automatically and kept in continual circulation. The battery is intended to be used for lighting and for small powers.

Details.—The jar is a low, rectangular box made of sheet iron, covered on the inside and outside with hard rubber, which renders it perfectly acid proof, while the box is light and strong. The porous jar is a narrow vessel with parallel sides, bent around parallel to itself repeatedly, somewhat like a broad, short letter **S**, the long parts of which (seven in number) are straight and parallel, forming practically several narrow porous cells communicating with one another so as to act as one, there being narrow parallel spaces between each two for a carbon plate. The porous cup has a hole at the bottom over a corresponding one in the jar, with a cock of special construction to drain off the liquid.

Zinc plate.—Each of the seven zinc plates is made of a number of rectangular pieces of thin sheet zinc, well amalgamated and afterward secured together so as to form one thick plate amalgamated practically throughout its whole mass. The object of this is to secure good amalgamation and to be able to use the cheap, impure zinc of commerce. These zinc plates are held in their porous cups, at and by their edges, by a three-sided grooved frame, the open side being at the top. The zincs are thereby held like a slate in its frame and may readily be replaced. This frame is made of copper, well amalgamated, and the contact between it and the plate is made by means of the mercury. This simple mode of supporting the zinc plates has many evident advantages; besides being readily replaceable, the zincs are completely immersed and consumed, and the contact is always good and clean. The liquid is dilute sulphuric acid.

Carbon plate.—The carbon plates are placed between the parallel portions of the porous cup as well as on the inside of the four sides of the jar, being mitered to hold them in place. The liquid is bichromate of soda.

Drain pipe.—There is a drain pipe connected with each cell, the object of which is to draw off automatically the old liquid at precisely the same rate at which the new liquid is being added, so as to keep the cell from overflowing or being drained. The liquid which has become passive is heaver than the fresh, active liquid and sinks to the bottom; the drain pipe must therefore lead it off at the bottom, while at the same time it must not allow the level of the liquid to change. To fulfill this condition it is made of two vertical concentric tubes, having an annular space between them; the inside one is open at the top at the normal height of the liquid and leads out through the bottom of the cell, and the outside one is open at the bottom and is higher than the normal level. The overflow, therefore, takes place from the bottom of the cell. There is one of these drains inside the porous cells and one outside. The supply of fresh liquid takes place in one corner of the cell and the drain is in the diagonally opposite corner, thus requiring the liquid to circulate continually through the winding parallel canals between the plates and the porous cup.

The liquids are supplied by lead tubes from two tanks above the battery. These tanks are filled by means of a very simple and ingenious, though not new, acid pump, consisting of a strong flexible rubber tube laid in the form of a semicircle and supported by a suitable guide; a wheel of slightly less diameter has rollers on its circumference, each of which in rolling over this tube compresses it and thereby pushes the liquid forward, similarly to the mechanical action of the intestines of the human body.

Size and capacity.—A cell 18 inches square and 6 inches high, the active surface of the seven zinc plates being about 5½ square feet, gives about 2 volts on open circuit and 100 ampères on short circuit, showing an apparent internal resistance (including polarization) of 0.02 ohms. The normal rate of discharge is 30 to 40 ampères.

The Automatic Electrical Corporation, limited (English section, bronze medal), exhibited a complete combination primary and secondary battery for house lighting.

Details.—A comparatively small and compact primary battery is automatically and continually charging accumulators, from which the lights are supplied when required. The elements are amalgamated zinc in dilute sulphuric acid in a porous cup, and carbon in a solution of bichromate of soda. The fresh liquids are supplied by canals and the spent liquids are led off through holes in the bottom of the cells, closed by valves of special construction. The drainage and refilling are operated electrically, every twelve hours for the acid solution and every three hours for the bichromate solution. A clock starts this operation. The jars are of hard rubber; the reservoirs are of sheet iron, lined with lead.

Output and cost.—The battery exhibited is said to light ten to twelve lamps of 10-candle power six hours per day, allowing 25 per cent loss in the accumulators, and to cost $100. The zincs last about a week. The cost of running, per 1,000 watts (by which watt hours are probably meant), taken from a report of a reliable authority, is about 50 cents, divided as follows: Bichromate, 20 cents; sulphuric acid, 4 cents; zinc, 12 cents; mercury, 1.2 cents; labor, 11.5 cents. At the rate of 2 watts per candle this would correspond to 500 candle hours, or 0.1 cent per candle per hour, which, for a 10-candle lamp, makes one cent per hour. A company in London undertakes to install and run the battery, supplying everything, including the wiring for ten lamps, charging at the rate of 1 penny (2 cents) per hour per 10-candle lamp, which is certainly very cheap for incandescent lights from primary batteries. They use as a sort of meter the quantity of liquid used. In their factory they utilize the residues.

Renard cell.—Another battery of some importance, owing to the great power developed from small, light cells, is that of Commander Renard (French section), shown in the accompanying illustration (Fig. 30) and called the chlorochromic cell, or the tubular battery, on account of its appearance. It is at present used for small portable table lamps, the battery being in the base of the lamp, and it was suggested to be used to propel the great military balloon "La France." It is, no doubt, the lightest battery ever made.

General description.—The cell may be said to belong to the bichromate class, in which the bichromate of potash is replaced by free chromic acid, and the sulphuric acid partially or entirely by hydrochloric acid. The cell consists of a long, narrow, cylindrical retaining cell of glass or ebonite. The negative electrode is a concentric tube, usually made of a very thin sheet of platinized silver; it may also be of carbon. The positive electrode is a long, thin rod of zinc, concentric with this silver tube and insulated therefrom. The general arrangement of a battery with twelve cells is shown in Fig. 30.

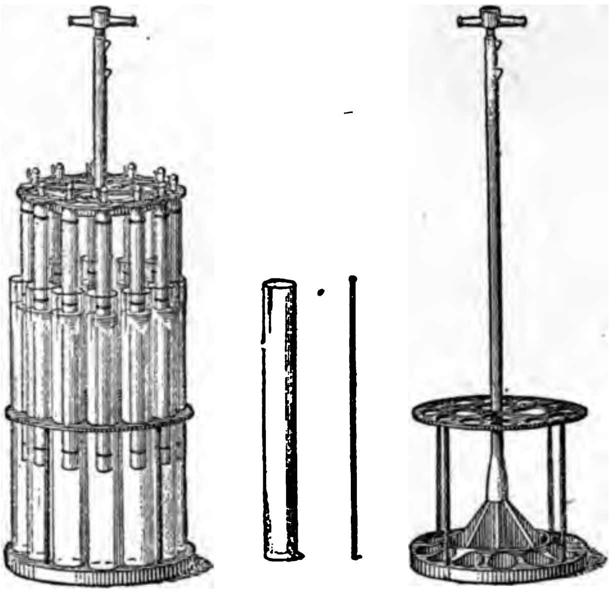


FIG. 30.—The Renard battery.

Solution.—A very thorough scientific and practical research seems to have been made to find the best proportions for the battery solution and to study its behavior. Of these results we give here only the most important conclusions. The tests are probably quite reliable. By replacing the usual sulphuric acid, part for part, by hydrochloric acid, it was found that the *rate of discharge* for the same cell was increased in proportion as the hydrochloric replaced the sulphuric, being increased fivefold when all the sulphuric acid was replaced, as compared with the usual bichromate solution with sulphuric acid alone. The *capacity* of all these new liquids, however, remains about the same; that is, as the rate of discharge increases the time of the discharge diminishes.

The more hydrochloric acid there is, the more tendency there will be to disengage free chlorine gas. The liquid should, therefore, not have too much hydrochloric acid and should not be prepared too long in advance. The mixture most frequently used for lighting, in which the proportion of sulphuric to hydrochloric acid (see below) is 80 to 20, is quite stable and can be mixed two or three months in advance. When no sulphuric acid is used the instability of the liquid is so great that it ought not to be used longer than two days after mixing.

The following three liquids composing the mixture may be prepared in advance and kept in stock:

Liquid A: Chromic acid, 530 grams; water, 770 cubic centimeters.

Liquid BCl: Commercial hydrochloric acid of 18° Baumé (or a specific gravity of 1.143).

Liquid BS: Dilute sulphuric acid of 26° Baumé (or a specific gravity of 1.25), consisting of 450 grams acid of 66° Baumé and 800 cubic centimeters water.

The greater the proportion of the liquid BCl used, the more rapid will be the rate of discharges and the shorter the time of discharge. The capacity is the same for all, being 50 to 60 watt-hours per liter, the discharge being stopped when the difference of potential has fallen to 1.25 volts per cell. The following figures are deduced from a table given:

Properties.—Proportions by volume of the liquids A, BCl, and BS, respectively, 100, 20, and 80; specific gravity, 1.27; maximum current, 3.5 ampères; coulombs, stopping the discharge when the current has fallen to half its maximum value, 10,630; watt-hours, 3.54, and therefore the mean volts must have been 1.20, and the ampère hours, 2.95; watt-hours per liter of liquid, 54.6; watt-hours per kilogram of liquid, 43.0; weight of liquid per horse-power hour (metric), 17.2 kilograms or 38.2 pounds. For the proportions 100, 100, and 0 (*i. e.*, without sulphuric acid), the figures are very nearly the same, except that the maximum current is 8.5 ampères, the mean voltage remaining exactly the same.

Renard's improvement therefore exists in two things—namely, in replacing the potash or soda salt by chromic acid, and sulphuric by hydrochloric acid. One or the other of these changes alone will not have much effect, but it is with the two combined that the discharging rate is increased fivefold, and the total capacity increased 50 per cent.

Positive pole plate.—The positive pole plate is made of a sheet of silver, covered with platinum. It is 0.1 millimeter or 0.004 inch thick, the platinum coating being only about 0.0025 millimeter or 0.0001 inch thick. The platinum is necessary for protection, as the silver is attacked slowly when the platinum does not cover it. It is bent into the form of a long, narrow cylinder, the lap of which is left slightly open so as to allow the liquid on the outside to circulate and get into the interior to the zinc. The diameter of this tube should be about 0.4 to 0.6 that of the retaining cell. The cost of such an electrode 1 inch in diameter and 9 inches long is $1. Three little hard-rubber rings in the inside stiffen it and insulate it from the zinc rod, which is passed through the holes in these rings. It may be replaced by a carbon cylinder, but platinized silver is preferred, as its conductivity is better and the weight and volume are less, the latter being practically nothing. It is very expensive, however, and should be replaced by carbon if the maximum output is not essential and the liquids not too concentrated.

Negative pole plate.—The zinc used is in the form of a thin zinc wire. It is made small in order to diminish the local action (which is proportional to the surface), and so that it may be consumed completely by one charge of the liquid. The smaller the surface of the zinc the more nearly is the consumption proportional to the current. Tests show that 1 liter of the liquid dissolves 85 grams of zinc. This would, however, require a zinc wire too small to be practicable, especially as the action is more rapid at the top than at the bottom, and would result in cutting it off at the top. It is therefore made slightly larger, in general 0.16 of the diameter of the cell, which is about one-fourth of an inch for the normal cell. It is not amalgamated for several reasons. It was found that after a certain point of concentration was reached, the amalgamated and unamalgamated zincs are attacked equally by local action. Furthermore, it increases the expense and makes such a thin rod as brittle as glass. Unamalgamated zinc also enables a leaden retaining tank to be used for table lamps, which would be destroyed by a single drop of mercury from the zincs.

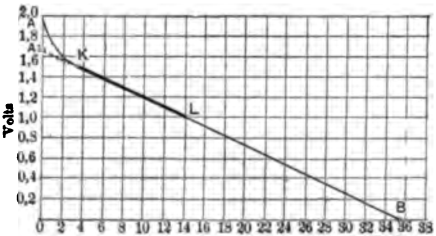


FIG. 31.—Renard cell; characteristic.

Characteristics.—The characteristic of a cell is the curve obtained from the values of the difference of potential and of the current, corresponding to successive values of the external resistance varying from infinity (or open circuit) to zero (or short circuit). For a theoretically perfect cell, that is, without polarization, as, for instance, in a Daniell cell, this ought to be a straight line, as in the accompanying diagram, Fig. 31 (excepting the curved part KA), in which 1.67 would be the voltage on open circuit and 35.7 the ampères of current on closed circuit. The *constants* of such a cell would be the electro-motive force 1.67 and the internal resistance 0.047 ohms, which is evidently the quotient of 1.67 volts and 35.7 ampères. The characteristic shown is stated to have been obtained from one of these cells without sulphuric acid. The points K and L are those between which the cell is used in practice, for which, therefore, the constants are those given above. For other cells, however, this characteristic is always a curve. By drawing a straight line through that portion of such a curve which represents the normal working conditions, and prolonging this line, the practical constants may be shown in the same way.

Output and capacity.—The following are some of the dimensions and capacities of these cells. Diameter of cell, 1⅜ inches; tube of silver, about three-quarters of an inch; zinc, about one-quarter of an inch; height, not given, but probably 9 to 10 inches; difference of potential while working normally, 1.20 to 1.25 volts; internal resistance, 0.17 ohm; discharge stopped when the voltage has fallen to about 1.12. The solution was the one described above, 100, 20, and 80. Twenty-four cells connected in series were discharged continuously through three lamps of 27 volts and 1.25 to 1.3 ampères each; the total quantity of liquid used was 6.3 liters; it ran 140 minutes, having given 347 watt hours, making 55 watt hours per liter of liquid, or 18 liters per kilowatt hour. Constructed as light as practicable, it will weigh 40 kilograms per kilowatt hour, everything included, or almost 66 pounds per useful horse-power hour. For practical batteries of this class, it is doubtful whether the weight can ever be brought materially below this figure.

The following are the dimensions and figures regarding the battery which is intended to propel the great military balloon "La France:" Cells, 4 centimeters diameter; silver tube, 3.2 millimeters; zinc, 6.4 millimeters. Total weight of a battery of twelve cells connected, six in multiple arc, 10 kilograms. The useful power at the end of one-half hour's running was 220 watts, thus requiring about four of these batteries per kilowatt; or with a motor, about four batteries, weighing 40 kilograms for a useful horse-power hour measured at the shaft. The weight that could be carried by the balloon was 400 kilograms, therefore making 10 horse-power, or 7.5 kilowatts for 1 hour and 36 minutes. While these results are very good and far superior to others obtained, the inventor himself admits that we can not hope that electrically driven balloons will ever be successful implements of war.

Table lamps.—The following data are given by the maker of a table incandescent lamp furnished with a battery of these cells in its base. Weight, complete, 35 pounds; height, clear, 33 inches; lamp, 25 candles; volts, 10 to 11; ampères, 4; mean duration, 5 hours; maximum, 8 hours; price, $60; cost of recharge, 50 cents; cost per candle hour, 0.56 cent. The liquid is raised or lowered by air pressure produced by a small rubber bulb.

References.—For a more complete description see the first volume of the Bibliothéque de la Revue de l'Aéronautique, a very complete abstract of which is published in l'Électricien, of Paris, Nos. 363, 364, March 29, 1890, from which the above illustrations were taken.

M. Gustave Trouvé (French section, gold medal) had an elaborate exhibit of primary batteries, chiefly for medical purposes and small lights and powers. They are almost all of the ordinary carbon, zinc, and bichromate type, and leave little to be described. The small portable and pocket cells for medical and surgical purposes, and for small lights, are arranged in convenient form, as regards the plunging of the plates and prevention of spilling the acids. A small portable lamp battery has loose ribs around it like those of an umbrella, which ordinarily are not noticeable, but if the cells should start to fall over these ribs spread out and prevent it from falling.

He exhibited, also, a small boat run by an ordinary plunge battery. Apparently the only novelty is that the motor and propeller are on the rudder and are geared together by a chain gearing. For some additional remarks regarding this boat, see under "Applications of Power," p. 94.

M. Trouvé uses a more concentrated solution than usual; his proportions (by weight) are: 1 part bichromate of potash, 8 parts water, and 3.6 parts sulphuric acid. The constants of the cells for the boat are: 1.9 volts, 0.07 to 0.08 ohm internal resistance; four cells will develop 14 kilogrammeters per second for two hours running before it falls.

Modifications.—Most of the batteries exhibited using bichromate of potash for a depolarizer, have the zinc in a porus cup in diluted sulphuric acid. Among the principal modifications were the following:

M. Crosse (French section, honorable mention) replaces the usual carbon plate by a sort of cage of thin sheet lead, perforated and filled with fragments of retort carbon. The lead acts merely as a receptacle and a conductor for the carbon. The lead cage is made of two concentric cylinders united at the top and bottom, the annular space between them being filled with the carbon fragments. A lead terminal leads off the current. He claims as the advantages, that it is not fragile like carbon plates; it is cheaper; it offers great surface of carbon, lowering the resistance, diminishing the polarization, and thereby increasing the rate of discharge; it overcomes the objection to the unreliable brass terminal secured to the carbon plate. A 1-pint cell costing 50 cents is said to have a capacity of 30 ampère hours, at a rate of from 1 to 5 ampères. A 1-gallon cell costing $3 has a capacity of 250 to 300 ampère hours at a rate of 6 to 20 ampères.

Overflow tube.—The following simple and ingenious overflow tube was used in a number of different batteries of this class. The liquid in such cells, after it has performed its function, is heavier and sinks to the bottom. In adding new liquid to the old, the overflow of the old liquid should be from the bottom of the cell. This is effected by means of a vertical glass tube outside of the cell, the upper end of which tube is bent around in a semicircle, forming a nozzle for the liquid to flow out of. The lower end communicates with the inside of the cell through a hole in the bottom. The top curved part of the tube must be just as high as the normal level of the liquid. When fresh liquid is added the old will, therefore, overflow automatically from the bottom. If this tube is connected to the cell by a flexible rubber tube, the cell can readily be emptied by bending down the tube.

Lagarde (French section, bronze medal) exhibited a battery for lighting purposes in which the carbons were revolved continually by an electric motor to agitate the liquid. The cells were arranged in a circle; the fresh liquid was supplied from a tank in and over the middle, the supply cock being opened electrically when the potential had fallen sufficiently. The zincs are perforated. The following data are given by the maker: Price of liquid, 4 cents per quart; 1 quart will run a 5-candle-power lamp for 1 hour. The price of the zinc, 40 cents; the set of twelve zincs will run 240 ampère hours; a battery of twelve cells gives 15 to 18 volts and 8 to 10 ampères, and costs $100.

In the battery of Mr. Pillet (French section), instead of raising and lowering the zincs the liquid is lowered and raised, respectively, by air pressure produced by a rubber bulb simultaneously on all the cells.

In the medical battery of Chardin (French section) this same principle is used to great advantage, making a clean, practically sealed cell, very well adapted for physicians and surgeons. The retaining cell is of porcelain, and consists of two parts. The upper one, containing the electrodes, is empty when not in use; the lower one is closed completely and contains the liquid. A tube communicates from the lower part of the upper to the lower part of the lower cell. By pumping air into the lower one, which is readily done by means of a rubber bulb, the liquid is forced up through this tube into the upper cell; by allowing this air to escape the upper cell is drained.

In the Bazin battery for lighting, the carbon plates are in the form of circular disks mounted on a common shaft which is revolved by a small electric motor; the revolving of the plates is claimed to diminish the polarization. In the curves of discharge exhibited, the difference of potential of 1 volt for currents of 9 to 10 ampères is shown to be remarkably constant for forty to fifty hours continuous discharge.

In the battery of Kornfeld (Russian section) the cells are very narrow, deep, rectangular boxes made of carbon plates cemented in some way at the edges, and heavily copper-plated on the outside. The box forms the positive pole; the zinc plate is lowered down into the box when in use, and is very close to the carbon on all sides, thus making the internal resistance very low. Liquid is supplied continually at the top, and is led out at the bottom in the usual way. The whole battery is very compact.

In the Chameroy (French section) battery the cell itself is a tube of carbon, the zinc being a concentric rod secured at the top and bottom. The liquid enters continually at the top and is led out at the bottom. The zinc rod is cast in the form of a screw with a very coarse, deep thread, whereby the liquid is made to circulate in passing down.

In the cell of Radiguet (French section, silver medal) the object is not only to lift the zinc out of its solution in the porous cup, when not in use, but also to empty this porous cup at the same time, to prevent diffusion of the liquids. To do this, there are two cups at right angles to each other, joined at their open end like the letter L inverted, and turning on a horizontal axis through this point, over one edge of the jar. One is porous and swings in and out of the jar, and the other is glazed and is outside. The zinc is placed in the porous one. To immerse the zinc its porous cup is turned vertically so as to be in the jar, and the liquid from the glazed cup flows into it. To withdraw the zinc, the two cups are rotated through a right angle, which empties one into the other.

In another cell of the same exhibitor, instead of using a zinc plate for the negative pole, he uses a copper tray or basket well amalgamated, filled with scraps of zinc and some mercury. The copper tray acts merely as a conductor, and is not attacked, if well amalgamated. The object is to use up scrap zinc.

In the Delaurier cell exhibited by Guérot (French section, honorable mention), designed chiefly for electro-plating, and consisting of zinc, carbon, and porous cup, the liquid used with the carbon is made of 87 parts ferro-chromic salt, 198 parts warm water, and 155 parts sulphuric acid. The liquid for the zinc is water, with a little of this added. The zinc need not be amalgamated. The chief advantage is cheapness.

Residues.—Among other exhibits properly belonging here was an interesting one of Mr. George Fournier (French section, bronze medal), which may prove of importance in cheapening bichromate batteries by finding a market for the residues of these cells. The exhibit comprised the various commercial products obtained from these residues.

His process of separating the residue into commercial products is briefly as follows: The residue coming from the batteries is a mixture of sulphate of chromium, sulphate of zinc, sulphate of potassium or sodium, sulphuric acid, chromic acid, and water.

The first process is to neutralize the free acid by means of scraps of metallic zinc. This is finished when the solution has become green instead of brown. During this process chrome alum crystallizes out, forming one of the commercial products, being used chiefly as a mordant. The oxide of chromium is then separated by precipitation at 212° F., by adding fragments of zinc or by oxide of zinc at ordinary temperatures. This is finished when the solution has become quite clear. This oxide of chromium is the second commercial product. The remaining solution is treated with chalk, which precipitates zinc oxide, together with sulphate of calcium. This is finished when the liquid does not become turbid when ammonia is added. The remaining liquid contains only sulphate of potassium or sodium, or both, depending upon whether the bichromate of potassium or sodium was used in the battery. If only one of these was used this liquid, evaporated to dryness, forms the third commercial product. To the mixture of oxide of zinc and sulphâte of calcium some sulphate of zinc is added until the solution is slightly acid, in order to be sure that no chalk remains; bichromate of potash is then added, forming a bright yellow precipitate of chromate of zinc, which is an excellent pigment and may be used for coloring paper, for paints, etc., having a great covering power, owing to the sulphate of calcium mixed with it. From the chromium oxides are then made different colors, mordants, chromic acid, metallic chromium, and it may be used in the iron and steel industries.

OTHER CELLS FOR LARGE OUTPUT.

Lalande & Chaperon.—One of the most interesting of the battery exhibits was the Lalande & Chaperon cell, exhibited by De Branville & Co. (French section, gold medal, for collective exhibit). It has gradually come into extended use, its numerous advantages giving it a very important place among batteries. It is a single fluid cell, with a solid depolarizing substance. It can be used for open circuits, for closed circuits, and for strong currents. The electrodes are amalgamated zinc and black oxide of copper; the liquid is caustic potash of 30 to 40 parts to the 100. The action is to dissolve the zinc and to reduce the copper oxide to metallic copper.

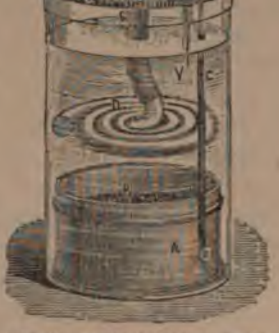


FIG. 32.—Lalande & Chaperon's cell.

Construction.—One of the principal forms, called the spiral form, is shown in the accompanying illustration, Fig. 32, in which D is the zinc spiral, and A is a thin sheet-iron box containing the copper oxide B and a copper-wire conductor, C, insulated where it passes near the zinc. The cell is 7¼ inches high and 4¼ inches in diameter. Another form, called the hermetic type, consists of a cast-iron bottle, forming the retaining cell and at the same time one pole, having the oxide of copper on the bottom. The zinc, suspended by an amalgamated brass rod, is held by the rubber stopper, which at the same time seals the cell. In the large hermetic type the zinc is in the form of a large flat spiral, presenting great surface, and the cast-iron bottle is closed by means of three bolts and a rubber gasket. In the trough form, for heavy currents, the iron cell is in the form of a very shallow, flat, rectangular box. The layer of oxide of copper on the bottom is covered with a sheet of parchment paper, and the zinc is a flat sheet, with a brass lug attached to it. The liquid is covered with a layer of some thick oil. When a number of these cells are to be used in series, as for incandescent lights, they may conveniently be placed one over the other. The size and style of cell depend on the purpose for which it is to be used. The large trough form, about 16 by 8 by 4 inches, is designed chiefly for lighting, small powers, electrolysis, etc.

Constants.—The following constants of these cells may doubtless be relied upon as correct. The electromotive force on open circuit is from 0.8 to 0.9 volt. The following table gives some of the constants for continuous discharge, through an external resistance equal to the internal—that is, for maximum work—in which case, therefore, the difference of potential or useful electromotive force is slightly less than half of that on open circuit.

	Internal resistance.	Ampères.	Capacity in ampère hours.
Spiral form	0.15	1.5 to 2	70
Hermetic form:			
Small	0.15	0.5 to 0.7	15
Medium	0.10	1.5 to 2	70
Large	0.035	6 to 8	540
Trough form:			
Small	0.10	3 to 4	235
Large	0.35	6 to 8	540

See also the constants in the expert's reports given below.

Properties and uses.—There being no great polarization, the cells can be used on closed circuits without any stirring or circulation of the liquid; the difference of potential on closed circuit is said to fall slightly at first and then to remain nearly constant until the materials are almost consumed. The quantity of zinc consumed is very nearly that required by theory, showing that there is almost no local action and that it is therefore not necessary to raise the zinc out of the liquid when not in use. It is, therefore, well adapted for lighting on a small scale, for telegraphy, electrolysis, etc. The formation of the solution of zinc does not appear to lower its resistance, while the reduction of the oxide of copper to metallic copper diminishes the internal resistance. In using them for lighting or other purposes requiring much energy, they are used at or near the point of maximum output, which is when the external and internal resistances are about equal. But under these conditions the useful potential is also reduced to about a half—that is, to 0.4 to 0.5 volt per cell. Thus, for incandescent lighting it is necessary to have about twice as many cells as the pressure in volts at the lamps.

A battery of the large trough cells is said to run two lamps in derivation, presumably 12 to 15 volt lamps. A precaution is necessary in running lamps; as the initial electromotive force is about double the normal, it is necessary to switch a resistance in series with the lamps at the moment of starting, in order to save the lamps from the strain of the high initial electromotive force at starting. For charging accumulators, 4 cells must be used for one accumulator. For medical purposes it may be used for a surgical lamp or cautery. On account of its great current capacity it is especially well adapted for signal work or similar purposes, in which strong momentary currents are required.

As there is no local action consuming the zinc when not in use it is very well adapted for open circuit work, especially when the intermittent current required is comparatively great. It is largely used for microphones and for calls and has been adopted by the Société Générale des Téléphones at their central stations. Notwithstanding the low electromotive force, one cell is said to be able to replace a Leclanché, probably owing to its low resistance and the fact that it does not polarize. The latter property adapts it very well for telephonic transmission of operatic, theatrical, and musical entertainments, requiring long uninterrupted service. In such service one of these cells is replacing five Leclanchés.

The cell gives off no odors, forms no creeping salts as in the Leclanché, requires no adding of water or other attention. The solution of zinc formed is very soluble and no crystals attach themselves to the zinc, which therefore requires no cleaning or scraping. The attention and cleaning required by the ordinary Daniell cells used in the large telegraph central stations are by no means a small matter. In the main telegraph office in London, for instance, there are 27,000 Daniell cells, requiring three miles of shelving.

Regeneration.—After the oxide of copper has been reduced by the action of the cell it can be rendered active again by exposing it to the air for several weeks or by roasting it at a red heat on an iron plate. The cell can also be regenerated by passing a current through it in the opposite direction.

Capacity.—For the same weight the cell is said to have five times the capacity in ampère hours, as compared with accumulators. But such a comparison is misleading, as current can not be used without potential; as the useful difference of potential is between one-half and one-quarter of that of an accumulator, a true practical comparison should include both, in other words, should be a comparison of energy and not of ampère hours. For the same weight the useful energy may perhaps be one and one-half or even two times as great.

Precautions and objections.—The principal precautions to be taken are that the liquid does not come into free contact with the air, as that changes it into carbonate; and care must be taken not to get the liquid on the hands or clothes. The former is overcome by hermetically sealing the cells, or covering the liquid with a layer of oil. The latter objection is overcome by supplying the salt in an iron box from which it is poured directly into the cell, and water poured over it, so that no handling of the liquid is required. Another objection was that the zinc was rapidly eaten off just at the surface of the liquid. This has been overcome by fastening the zinc to an amalgamated brass rod or strip, so that the zinc is wholly immersed. There appears to be no local action if the brass is well amalgamated.

The prices are from $1 for the small one to $4 for the large trough cell. A recharge of zinc, oxide of copper, and potash costs about 80 cents for a small trough and about $1 for a large one.

These cells have been adopted by the Société Général des Téléphones, by the Administration des Postes et des Télégraphes, and are used among others in the London Post and Telegraph department.

Tests.—The following extracts are taken from various reports: M. E. Hospitalier discharged the small form illustrated above, Fig. 32, through 0.8 ohm, obtaining about half an ampère for 6 days' continuous running, or 259,000 coulombs (about 70 ampère hours). The theoretical capacity of the 88 grains of zinc consumed is 260,000 coulombs, showing an almost entire absence of local action. For full report see l'Électricien, August 1, 1883. Dr. d'Arsonval obtained 25 ampères from this one, and 106 from the large one, on short circuit. He found that by increasing the temperature from 20° C. (67° F.) to 50° C. (122° F.) the current increased from 4 to 12 ampères regularly with the temperature, and as the electromotive force remained the same this increase of current was due to diminution of the internal resistance. He also finds that there is no local action. See La Lumiére Électrique, August 25, 1883. In the Electrician (London) January 25, 1884, Sir William Thomson gives some results which he obtained. In La Nature, December 1, 1883, Hospitalier gives some results obtained with a small light.

CELLS OF THE LECLANCHÉ TYPE.

The chief exhibit of cells of this class was that of Leclanché & Co. (French section, gold medal), the original makers of the famous Leclanché cells.

Original cells.—These cells were usually made of a porous cup containing a plate of carbon and filled with broken fragments of carbon and native peroxide of manganese (the mineral pyrolusite of commerce); the negative pole is a zinc rod, and the liquid is chloride of ammonia, the sal ammoniac of commerce. The zinc is amalgamated and the solution should be a saturated one.

Modification.—The improvement made some time ago, now already well known, and fast replacing the porous cup pattern, was to make hard, conglomerate blocks of the peroxide of manganese with the carbon, which blocks are held to the carbon plate by rubber bands; this replaced the porous cup and its loose contents. The resistance and polarization are thereby diminished, and consequently the useful difference of potential and current increased. These conglomerate masses are made of broken pieces of retort carbon, peroxide of manganese, and shellac, under hydraulic pressure.

Recent improvements.—The more recent improvements exhibited were the following: The conglomerate mass is made in the form of a hollow cylinder having a metallic terminal fastened to the top, as seen in the accompanying illustration, Fig. 33. The zinc rod, having a tinned wire terminal at the top, and a small rubber cap at the bottom is placed inside this cylinder and is held concentrically by the lid, as shown. This increases the depolarizing power of the peroxide of manganese, it being a more rational disposition of that material; the resistance is diminished still more, and the distribution of the current and consumption of the zinc is more symmetrical; the volume and weight are also diminished by this construction and the unreliable rubber bands are dispensed with. This construction enables the price to be diminished 25 per cent. The constants of this cell are: Electromotive force 1.5 volts, internal resistance (a few days after being set up) 0.4 ohm; weight of positive pole 1¼ pounds; price of cell complete 73 cents.

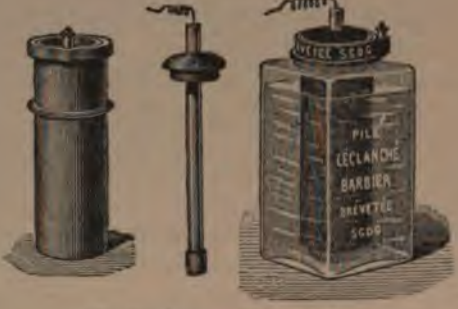


FIG. 33.—Improved Leclanché cell.

New salt.—Another one of their novelties is a new salt, to be used in place of the sal ammoniac. The latter has the very objectionable feature that crystals deposit on the zinc which thereby becomes insulated and is rendered inactive, and which causes the zinc rod to be eaten through or "cut off" at the top of the liquid long before it is consumed below. The positive pole also becomes clogged with these crystals. The new salt, which is said to be a mixture of 75 per cent of ammonium chloride and 25 per cent of chloride of zinc obviates the formation of these adhesive crystals and thereby keeps the zinc perfectly clean, enabling it to be consumed evenly and completely. It sells for 26 cents a pound.

Dry cell.—Another of their improvements for which they claim great future is their so-called "dry cell," a poorly chosen name, the action of all such cells depends on their property of keeping *moist;* a better name would be humid or moist cells. It consists of a cylindrical vessel of zinc which forms the retaining cell and the negative pole; in this is a conglomerate cylinder similar to the one described above. Between the two is a mass of plaster of Paris, moistened with a solution of their new salt; the top is closed with wax. It is sold ready for use. It has the great advantage of requiring no setting up or cleaning, and is particularly applicable in cases where the cells are jolted about, as on trains, boats, etc. Its capacity appears to be almost the same as that of the usual cells (see Fig. 34). It sells for 87 cents.

The diagram, Fig. 34, gives a series of discharges of different cells, showing some of their qualities. The discharges were continuous, through an external resistance of 10 ohms.

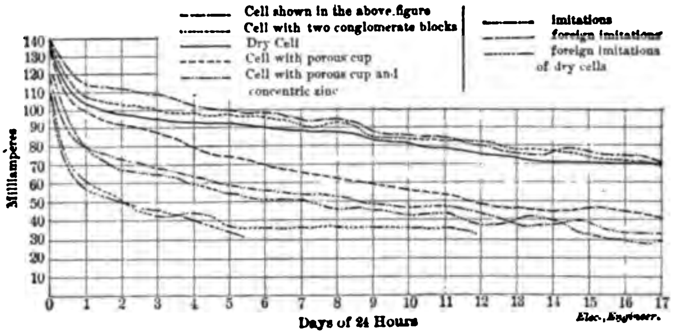


Fig. 34.—Curves showing the discharge of different Leclanché cells.

After thirty days' continuous discharge the dry cell still gave 50 milliampères; the discharge of the ordinary porous cup fell to this current in about fifteen days. The replaceable conglomerate blocks are of such a size that they are consumed in the same time that one zinc will last.

Minor improvements.—Some of the minor improvements are as follows: In the porous cup cells the porous cups have slits cut in them to increase their porosity. A "cavalry battery" to be used on horseback in military service is made of small carbon plates having a zinc plate cemented to it on one side with a paste of boiled oil and plumbago, making an electrical and mechanical contact; these are piled one over the other with sheets of blotting paper between them; the whole is strapped together without any retaining-cell. To render it active the whole is dipped into the solution long enough to merely wet the blotters. All the cells are evidently connected in series by this construction.

Instructions.—The instructions regarding their cells are: that the zinc should be amalgamated and the solution completely saturated; that the new solution should be added when the old becomes milky;

that the addition of chloride of zinc solution is advantageous, and that tinned wire is preferable for connecting the cells.

Other exhibits of Leclanché cells.—Among the minor improvements of the Leclanché type of cells, as exhibited by different exhibitors, are the following: Henri Serrin (French section, honorable mention), exhibited retaining cells made of a single block of wood, lined on the inside with a waterproof coating. Two or more holes may be made in the same block, making a battery of cells complete in itself. He claims cheapness, strength, and lightness; being sealed there can be no creeping of the salts, and the cells are as convenient as the "dry cells." He claims that the blocks cost only 0.8 cent each to make. A complete battery of two cells in one block sells for 39 cents. He furthermore makes his contact on the carbon with a tinned zinc strip, so as to avoid the oxidation of the usual brass terminal.

J. Warnon (French section, bronze medal) exhibited a new form of terminal to the carbon plate. He claims that in the usual construction, local electrolytic action forms a salt between the metal terminal and the carbon, destroying the contact. In his terminal the brass binding post is tipped on its inside end with platinum, which presses against the carbon by forming the end of a screw which passes through the cast lead cap of the carbon. He replaces the porous cup by a coarse linen canvas bag soaked in turpentine and resin, inclosing the active material and tied around the carbon. He claims for this, cheapness and rapidity of discharge. For instance, a half-gallon cell with four carbons and selling for $1.16 gave 40 ampères on short circuit. He claims that he can regenerate the peroxide of manganese of old cells, so that it can be used over again. This is probably done by charging the cells in reverse direction. He also exhibits some small portable medical cells, 1 by 1 by 2½ inches, selling for only 19.3 cents each.

The Western Electric Company (United States section) exhibited Leclanché cells with the porous cups replaced by cotton bags; also porous cups with slots, and canvas around them; also porous cups with holes near the top to replace the usual glass tubes through the top; also glazed cells with numerous holes and a canvas bag on the inside, to replace the porous cups.

Ch. R. Goodwin (French section) makes a large cylinder of the conglomerate mass, having secured to it a zinc rod, forming together one piece. This he claims will give 2 to 2½ ampères on short circuit.

Messrs. Renault & Desvernay (French section, honorable mention) show a "dry cell" in which the moist mass is a siliceous gelatine.

OTHER CELLS FOR SMALL CURRENTS.

Among other cells for small currents not of the Le
are the following:

Chas. Chardin (French section, silver medal), one of the principal makers of electro-medical apparatus, exhibited some very conveniently arranged medical cells, which he claims are almost half the weight for the same capacity, and which do not require the cleaning and attention of other cells, an important item for a physician. While the first cost is greater, the cost of maintenance is more than correspondingly cheaper. The cells consist of a high, narrow, cylindrical, retaining cell, having a carbon and a zinc rod fastened on the cover, which is common to all the cells of a battery. The liquid is bisulphate of mercury, filling about one-third of the cell; on this floats a large cork, which fits the retaining cell loosely. In the state of repose the electrodes are separated from the liquid by this floating cork, which also serves to almost seal the cell so as to prevent slopping. By depressing the electrodes this cork is forced down, and in doing so forces the liquid up to the electrodes, thus putting the battery into action. As it is necessary to raise the electrodes out of the liquid when not in use, the box containing all these cells is so arranged that the lid can not be closed until the electrodes have been raised, which is done by a counterweight or spring. The top of the box contains all the ordinary accessory apparatus used for medical purposes. The electro motive force is 1.526 volts.

The cell of Dr. Fontaine-Atgier, exhibited by Mors (French section), is also intended for medical purposes. The electrodes are zinc and copper, the latter having a mixture of peroxide of manganese and coke secured around it by means of a sack of thick, ordinary pasteboard. The liquid is potassium hydrate (the soapmaker's potash of commerce); the electromotive force is 1.49 volts. The advantages claimed are, that it can be used on open circuit work, it is quite constant and the resistance is low. A battery of a large number of cells is constructed without retaining cells, as follows: All the electrodes, as described above, are fastened in pairs connected in series, on a common lid, the zincs being tied against the pasteboard. To put it into action, the whole is dipped for a moment into a large tank containing the liquid, and is then withdrawn. Enough liquid is retained in the pasteboard to actuate the battery. The whole is arranged to be convenient for transportation.

L. Maiche (French section) exhibited a battery in which the depolarization is effected by the air. The negative electrode consists of scraps of zinc in a bath of mercury; the positive is made of a receptacle in the upper part of the jar, containing fragments of crushed coke which have been coated with a very thin layer of platinum black; this coke rests half in and half out of the liquid, allowing the air to be absorbed by the platinum black. It is claimed that one of these cells has been in action more than ten years without any attention. He also exhibited a salt to be used in place of sal ammoniac, which he says will dissolve eight times the quantity of zinc as compared with sal ammoniac.

CHEMICALLY PURE ZINC.

It is in place here to mention the exhibit of Louis Cahaigne (French section, bronze medal), who exhibited chemically pure zinc produced by a new process, by means of which it can be made cheaply. It is well known that local action in the zinc used in batteries is caused by the impurities in the zinc; if, therefore, the zinc is free from other metals it will not be attacked on open circuit, and will not need to be amalgamated, which is a source of trouble and entails no small expense. The process of this exhibitor enables him to make chemically pure zinc at a sufficiently low price to enable it to be employed in batteries. It can be made for 1 franc per kilogram, or 8.8 cents per pound, which is very low. Numerous reports from chemical experts were given, showing this metal to be really chemically pure.

Another process of obtaining pure zinc was exhibited by M. L. Letrange. This is an electrolytic process, but it belongs to the department of metallurgy and is, therefore, not included in this report.

MISCELLANEOUS.

Messrs. Perreur-Lloyd et Fils exhibited a battery in which the residue of the action was sulphate of copper. But as the electricity generated was a mere by-product, the object being to manufacture sulphate of copper, the description is given under the heading, "Electrochemistry," p. 154.

Mr. Thomas A. Edison exhibited a "chalk" battery, but as the action is probably thermic, it is described under that heading.

References.—For other generators of electricity, see respective headings. For battery carbons, see "Carbons," under "General Supplies." For substitution of dynamos for batteries on telegraph lines see "Telegraphy."

ACCUMULATORS.

GENERAL.

The lead accumulator as a practical commercial battery may be said to have originated about the time of the first electrical exhibition in Paris, in 1881, the chief inventors, Planté and Faure, being both from France. Although probably more capital has been spent in developing it, than in any other electrical appliance, its progress has been very slow and the results, even at the present time, are not what was expected or desired. They are, however, in sufficiently good form now to find considerable application in practice, which is growing very fast. But they still leave many points to be desired. They are at best heavy and expensive, and deteriorate rapidly; many of them, of the grid type, require considerable care, without which they will suffer greatly.

Development.—The development, as shown at this exhibition, is chiefly in the direction of details of construction and modifications intended to keep the active material from falling off and out of the supports. A number of developments have also been made in the Planté type, possibly because this form is not patented; these have been mainly in the direction of first preparing the material in the form of finely divided lead so as to be more readily formed electrically. Severally forms differing in their chemical action have been proposed, but as yet they are not any better than the lead cells.

Exhibits by countries.—The exhibits were principally in the French section, with a few from Switzerland, Belgium, Italy, and Austria.

Definition of terms.—Before describing the exhibits in detail it will be well to define some of the terms used, as there is great ambiguity respecting them, which unfortunately many manufacturers take advantage of to deceive purchasers and to make their goods appear much better than they really are. This has been carried to such a degree that statements of manufacturers have very little value. In giving the capacity of an accumulator, for instance, manufacturers often give the amount with which they are charged, which can evidently be increased very greatly by simply continuing the charge. It is the amount which they will yield on a single continuous *discharge* which is the important factor for determining the real capacity of a cell, and by which the number and size of the cells required for a plant must be calculated. This will here be termed the *effective capacity* and is the only one of importance. The true capacity should include the *mean effective difference of potential;* this is rarely higher than two volts, at a proper rate of discharge, and should never be less than 1.8 volts; a mean of 1.9 volts may therefore be taken as a constant, which, if anything, is too high. A discharge should be continuous and should be considered as ended when the difference of potential has fallen to 1.8 volts. The *capacity per pound of plates* is the effective capacity divided by the total weight of the plates complete; this weight should include all lugs and attachments to the plates which are a necessary part of them. The capacity of a cell depends also on the *rate of discharge*, which should therefore be stated; this, in order to compare different accumulators, is generally reduced to the *rate per pound of plates.* The usual rate is about half an ampère per pound of plates, but this is too slow a discharge for many cases, especially for traction purposes, in which the weight of the battery has to be carried by the locomotive mechanism. A good accumulator should stand a discharge of 1 ampère per pound without injury. A better way of stating the rate of discharge is to give the ratio of a discharging current to the capacity; for instance, if a 100-ampère hour cell is discharged at 20 ampères, the rate is 20÷100 or one-fifth; but this is evidently the reciprocal of the *time* *of the discharge* in hours. This time is, therefore, an important factor; the shorter it is, for the same capacity, the better the cell, as the capacity diminishes rapidly with the time. A similar figure for the shortest time in which they can be charged is also of importance. The *efficiency* of a cell should really be the ratio of the *watt hours* instead of the *ampère hours;* the latter is the one usually given because it must necessarily be considerably higher, but it is the former which expresses the real efficiency of the storage of the power. The mean voltage of the charge and the discharge must be known to determine this, but it is seldom given; it may be assumed, however, that for any good accumulator the mean effective voltage of the discharge is 1.9 volts, and that of the charge is about 2.25, making an *efficiency of the volts* of about 85 per cent. If the efficiency in ampère hours, usually given, is multiplied by this efficiency in volts, the result will be the *true efficiency* of the energy stored, in watt hours. In all cases it should be stated whether a given efficiency is in ampère hours or in watt hours. The terms positive and negative plates will be used as defined by the electrical congress of 1889, namely: The positive plate is the one forming the positive pole of the cell, and is connected to the positive pole of the charging circuit; it is therefore the brown or peroxide plate. The negative is the other one.

Jury tests.—A number of the accumulators exhibited were tested at the Laboratoire Central d'Électricité for the jury. A few of the results obtained are given below in the detailed description. Although these results are correct, yet they were not all obtained under the most favorable conditions for the cells, and therefore should not be taken as the best results obtainable. The charging, for instance, was in all cases continued until the difference of potential reached 2.5 volts, which is too high, and consequently the efficiency is lower than it should be. On the other hand the capacity is for this reason greater than it would be ordinarily. The results obtained are not very good and are considerably lower than those given by the makers.

Mean capacity.—In general, for a good accumulator one can not count on much more than five effective ampère hours per pound of plates, which at 1.9 volts gives 9.5, or, say, 10 effective watt hours per pound of plates, which is equal to about 75 pounds of plates per effective horse-power hour, or 100 pounds per kilowatt hour. The proportion which the weight of the plates bears to the whole weight of the cell complete differs very widely in different systems, being in these tests between the limits 82 per cent for the Faure-Sellon-Volkmar and 44 per cent for the Dujardin. Assuming 75 per cent as a high average for a light cell, gives therefore about 100 pounds of cells complete per effective horse-power hour, or 133 pounds per effective kilowatt hour. These figures regarding the weights of the accumulators are of importance only when the cells are to be transported, as for traction purposes, car lighting, etc. If they are to be permanently installed in one place their weight is of little consequence. It is in all cases of interest, however, to the electrical engineer as it shows in a degree how effectively the materials are utilized.

Cost.—A poor practice has arisen in France (started, we believe, by the makers of a heavy accumulator) of selling accumulators by the pound. This is very irrational, as the better an accumulator is the lower would have to be its selling price for the same output in order to compete. Unless such a statement is combined with a guarantee of a certain capacity per pound it has no value, and, worse than that, it deceives the purchaser. The two statements might therefore just as well be combined at once, making a uniform system, which is rational—that is, to give the price per effective ampère hour. Such a system enables any electrician to calculate readily the cost of the cells for a certain output, and does justice to the better accumulator.

Comparative statement.—In order to be able to readily compare some of the common features of a number of the accumulators exhibited, the following table is prepared, giving a few practical deductions not usually contained in the published descriptions, and from which some fair, average, and useful figures may be taken. The results were all deduced directly, and only, from data published by the makers in their circulars. They are therefore quite fair for the makers, but not so for the purchasers, because some of the data as given have undoubtedly been exaggerated.

The first column contains the capacities, which are probably too high; the second, the capacity per pound, therefore also too high, the weight also being often underrated. It will be seen that from 4 to 4.5 may be assumed as a mean. The third, containing the rate of discharge, is probably nearly correct, but it is doubtful whether, at those rates, the capacities will be as stated, for the maximum rates have been taken in all cases. Half an ampère per pound may be taken as a fair mean. The greatest rapidities of discharge, in the fourth column, are probably close to the real values; a 5-hour discharge appears to be about the most rapid, the average being considerably slower. The fifth column has been deduced in order to endeavor to obtain an approximate idea of the average cost of accumulators, which has here been reduced to a common rational basis of cost per ampère hour. The prices used in this deduction are list prices, which are always subject to discounts, but at the same time there are generally a number of extras which tend to balance this discount, besides the fact that the capacities are generally considerably overrated, so that the figures here obtained, the quotient of the two, are probably not far from the true values. From 7 cents per ampère hour for the smaller ones to 4.5 cents for the largest may be taken as a rough mean. Of course these values will depend largely on whether the cells are for rapid or for slow discharge, also on the nature of the retaining-cell and other factors, and are therefore no criterion, but they will answer very well as a general guide.

The classification is made according to the capacities, the sizes selected from the circulars being those corresponding most nearly to 100, 500, and 2,000 ampère hours. The data for the copper-zinc accumulator, whose eletromotive force is 0.75 volt, have been reduced to equivalent cells of 2 volts, in order that they may be compared directly with the others.

	Capacity in ampère hours.	Capacity per pound of plates.	Rate of discharge in ampères per pound of plates.	Rapidity of discharge in hours.	List price in cents per ampère hour.	Nature of cell.
Original Planté cell of 1860	17.15	7.25	....	....	....	
Huber	90	6.8	1.0	6.9	5.9	Glass.
Gadot	93.5	4.5	.87	5.2	6.6	
Faure-Sellon-Volkmar	100	4.5	.91	5.0	7.7	Ebonite.
Pollak	100	3.2	.63	5.0	8.7	Wood.
Garassino	100	6.0	.90	6.7	5.8	
Schoop	115	2.7	.48	5.8	6.5	Glass.
E. P. S.	120	....	....	3.0	9.3	Wood.
Elwell & Co. (copper-zinc)	200	39	4.9	8.0	3.1	
Elwell & Co., reduced to 2-volt cells.	2.0	13	....	8.0	9.3	
Cély (Sarcia)	250	4.5	.45	10.0	6.8	
Faure-Sellon-Volkmar	400	4.6	.69	6.7	4.3	Composition.
Pollak	400	3.2	.63	5.0	5.3	
Garassino	400	6.1	.91	6.7	3.9	
Gadot	475	3.2	.67	4.8	5.9	
E. P. S.	500	....	....	11.0	4.35	Glass.
Cély (Sarcia)	500	4.5	.45	10.0	5.8	
Schoop	500	2.5	.45	5.4	4.8	Glass.
Huber	565	7.1	.69	10.0	4.3	
Faure-Sellon-Volkmar	2,000	4.5	.68	6.7	3.9	Composition.
Cély (Sarcia)	2,000	4.5	.45	10.0	4.3	
Elwell & Co. (copper-zinc)	2,100	41.0	6.2	7.0	2.0	
Elwell & Co., reduced to 2-volt cells.	2,100	13.7	....	7.0	6.0	

Detailed description.—In the following detailed description the cells are divided into those belonging to the Planté type, the Faure type, and those belonging to neither.

CELLS OF THE PLANTÉ TYPE.

Planté's original accumulator.—In the personal exhibit of the late Gaston Planté (French section, grand prize) there were exhibited the plates of an accumulator of considerable historical interest, as they had constituted what was undoubtedly one of the first practical accumulators ever made. The plates shown were mere sheets of lead 19 inches long and 8 inches wide, one piece was light brown and the other gray. In the accumulator they had been rolled up together spirally in the well-known Planté form. The following data accompanied it: "Made in 1860; unrolled in 1885; weight of both plates, 1.075 kilograms; one discharge deposited 20.425 grams of copper, which is equivalent to 61.765 coulombs." This capacity, reduced to more modern terms, is equivalent to 17.15 ampère hours, which therefore reduces to 15.95 ampère hours per kilogram of plates, or 7.25 per pound of plates. This result, obtained from the first accumulator thirty years ago, is even better than that obtained by many of the "improved" forms of the present day (see table above), including even the Faure type, in which the capacity is generally from 4 to 6 ampère hours per pound of plates, though more is often claimed by the inventors. This shows that as far as capacity per weight is concerned no progress has been made.

Dujardin.—The plates of the accumulator exhibited by P. J. R. Dujardin (French section, silver medal) are made of thin horizontal bands of rolled lead about three-eighths of an inch wide, having a roughened or ribbed surface, which are piled one over the other and connected together by a frame of lead cast around them, so as to form a plate three-eighths of an inch thick laminated transversely. In its form it is, therefore, very similar to the old well-known Kabath plates.

The chief novelty is in the process of forming the plates, which he claims can be done in 8 hours by a single charge, in place of the long, tedious formation in the usual Planté process. This he does by adding a certain salt to the sulphuric acid and using a very strong current for forming; this salt is used only in forming. It is a modification of the well-known process of hastening the formation by adding some nitric acid, the salt used having presumably the same function, namely, of assisting the more rapid oxidation of the lead. The objection to the nitric acid is that it is so hard to get rid of afterwards, for if any traces of it remain it will continue to oxidize the lead so that the whole frame is soon destroyed. Whether the particular salt used is more readily washed out of the plates after formation remains to be seen. If so, it is no doubt a valuable improvement over the ordinary process.

The negative plates are made of positives reduced by reversing the current. The plates being exceedingly porous, he is enabled to use fewer of them. In the cells shown there were one positive and two negative plates. The space between the plates is filled with a granular preparation of a burnt silicate which is exceedingly porous, resembling a sponge, and which renders contact between the plates practically impossible, but the internal resistance is probably increased considerably thereby. It is evident that an accumulator of this form will stand a very great amount of abuse without injury.

The following are some of the results of a test made for the jury: Weight of plates, 44 pounds; weight of cell complete, 90 pounds;

charge 375 ampère-hours, at 10 ampères; discharge 299 ampère hours, at 40 ampères. Deductions: 6.8 effective ampère hours per pound of plates; efficiency in ampère hours, 80 per cent; rate of discharge, 0.9 ampère per pound of plate; time of discharge, 7.5 hours. The charge was probably continued too long. In another smaller cell the results and deductions were as follows: Plates, 22 pounds; cell complete, 49.5 pounds; charge, 192.8 ampère hours at 20 ampères; discharge, 125.6 ampère hours at 20 ampères. Deductions: 6 ampère hours per pound of plates; efficiency in ampère hours, 62 per cent; rate of discharge, 0.9 amperes per pound of plates; time of discharge, 6.3 hours.

Pollak.—In the Pollak accumulators (Austrian section, silver medal) the spongy lead is formed on the plates themselves by a chemical method, as follows: The plate is covered with a paste made of a salt of lead (the chloride or the sulphate, we believe) which is then covered with a plate of zinc and immersed in acid. By a combined chemical and electrical action, the zinc is dissolved and the lead salt reduced to spongy lead, which is said to be very adherent. For positive plates these spongy lead plates are oxidized by the ordinary electrical process. The lead plates for holding this material are made in the form of a sheet with numerous minute teeth perpendicular to the plate; the material is held in place between these teeth which, when bent over slightly, after the active material has been put on, will form short hooks and will thereby tend to lock the material on to the plate. The reduction of the lead salt to spongy lead is said to require twenty to twenty-four hours. The chief claims for this accumulator are that it can be charged in six hours and discharged in five hours. This is undoubtedly a rapid rate, but it is permissible with almost any Planté accumulator. Strictly speaking, however, this belongs to the Faure type rather than to the Planté.

An ingenious modification, though not new, is the compound cell in which one retaining cell is divided off into several separate water-tight compartments by the plates themselves, which are secured to the box on their three edges by water-tight joints of soft rubber. One half of each plate is therefore negative and the other positive, each plate belonging to two neighboring cells. The object of such a compound cell is to increase the volts at the expense of the ampères, by combining several small cells in one receptacle. It is very necessary, of course, to guard against having any holes through the plates. This form is light, portable, and compact, and is especially well adapted for small lights.

Simmen.—In the Simmen accumulator (French section) the plates are made of fine hair-like threads of lead, made by pouring melted lead through a sieve and thence directly into water. This material is then compressed into plates, and a frame of lead cast around it. It is a question whether they will hold together after being thoroughly peroxidized.

Garassino.—In the Garassino accumulator (Italian section, bronze medal) the plates are made of a rolled sheet of lead having depressions and ribs, upon which is deposited, electrolytically, spongy lead; this is then compressed on to the plate forming a porous coating on the frame, which is readily oxidized for the positive plates by the usual Planté process.

Cély.—For the Cély cell, which might be classed among these, see below under the Faure type of cells.

CELLS OF THE FAURE TYPE.

Faure.—Philippart Frères (French section, silver medal) had the largest and most complete exhibition of accumulators. They are the makers under the Faure patents in France, and under the Volkmar patents for the grid, and the Sellon patents for the inoxidizable alloys of lead and antimony for the grids. They represent the Electric Power Storage Company in France. Their accumulator is too well-known to be described here. Their recent improvements are in the details of construction, the grid remaining the same as it has been. The present form of the plates is seen in Fig. 35. The negatives alone rest on the bottom of the cell, while the positives are supported on insulating blocks resting on a shelf attached to the negatives. The positives may readily be lifted out by the sort of bridge piece in the center. The construction, though complicated, is quite practical, except that it does not permit the removal and

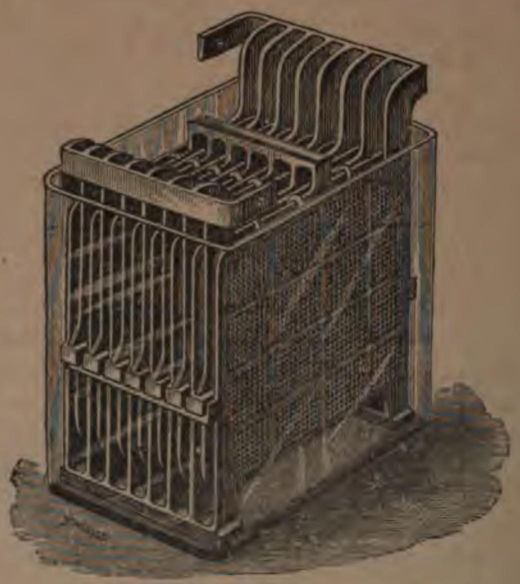


FIG. 35.—Accumulator; by Philippart Frères, France.

changing of a "sick" plate. Another improvement is their "twin" plate shown in Figs. 36 and 37, which explain themselves.

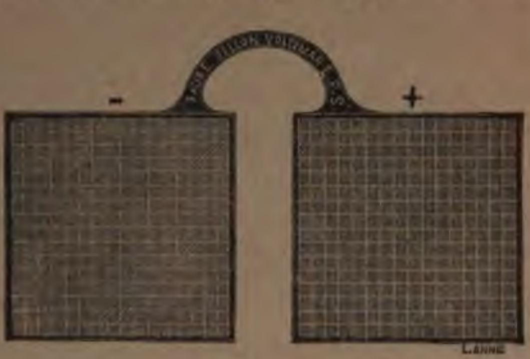


FIG. 36.—"Twin" accumulator plate.

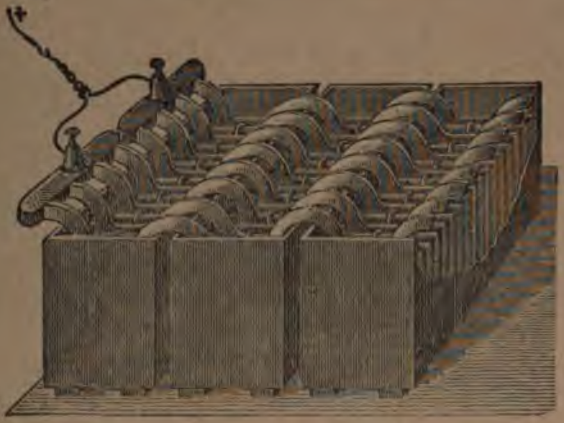


FIG. 37.—Phillippart Frères accumulator with "twin" plates.

This is a very ingenious contrivance for overcoming all soldered or other connections between cells, and furthermore enables any plate to be removed, examined, or changed, even while the cells are being charged or discharged. It has the slight disadvantage that there is no equalization of the capacities of all the like plates of a cell; they must therefore all be made of exactly the same capacity. This company appears to be selling large quantities of accumulators; they claim that, if properly taken care of, the plates will give no trouble. Their cells are used largely for house, as well as central station lighting, especially in England. They undertake to keep the cells in good order for from 15 to 30 per cent of the list price, per year. The test made for the jury gave the following results: Weight of plates, 26.8 pounds; weight of cell, complete, 32.7 pounds; charge, 137.9 ampère hours at 5.5 ampères; discharge, 108.5 ampère hours at 8.5 ampères. Deductions: Capacity, 4 ampère hours per pound of plates; rate of discharge, 0.32 ampères per pound of plates; time of discharge, 13 hours; efficiency, 78.5 per cent. Notwithstanding the very low rate of discharge, the capacity per pound is not very good. At a high rate of discharge the capacity falls rapidly.

Historical.—Among their exhibits was one of the original Faure cells of 1881, consisting of sheets of lead having the active material held upon their surfaces by pieces of felt tied around them.

Julien.—Another large exhibit of accumulators of this kind was that of the Julien cell, exhibited by the Société Anonyme l'Électrique (Belgian section, gold medal). This accumulator differs from the Faure-Sellon-Volkmar only in details of construction; the general nature of the grid is the same. The plates are as a rule smaller, as are also the meshes of the grids. They claim as their point of superiority over the Faure-Sellon-Volkmar that their grid is not oxidizable and will therefore not only last longer but will not suffer as much from use. They claim to make their grids of an alloy of lead, antimony and mercury, which is said to be inoxidizable. While this may be so in a measure, it is not absolutely so, as the grids will corrode in time. The usual type of their cells differs little in appearance from the simple, well-known form. One prominent feature is that all connections in and about the cells are either soldered with homogeneous solder or are made by means of clamps of the same alloy, which is quite hard, not at all like lead. The following details may be of interest. The size of the usual plates is 7 inches square and one-eighth of an inch thick; distance between plates, about three-sixteenths of an inch; the meshes in the grids are one-fourth of an inch square; weight of a grid, 2.45 pounds; weight of a plate, 4.36 pounds; the weight of the active material is therefore about 44 per cent of the weight of the plates; in the bottoms of the glass jars are two inverted V-shaped ridges which support the plates clear from the bottom. The following are the results of the test made for the jury. Weight of cell, complete, 40.4 pounds; charge, 185 ampère hours at the rate of 12 ampères; discharge, 133 ampère hours at the rate of 34 ampères. Deductions: The weight of the plates was not given, but, assuming it to have been at the most 26 pounds, gives 5.1 ampère hours per pound of plates and rate of discharge of 1.3 ampères per pound of plates; time of discharge, 3.8 hours; efficiency in ampère hours, 72 per cent. It will be noticed that the rate of discharge is quite high, being more than one-quarter of the capacity, as the discharge was in less than four hours. The results are therefore quite good.

An interesting novelty exhibited by this same company was a battery of accumulators in which the plates themselves formed the retaining cells. The plates are made in the form of truncated cones closed at the small end; they have circular horizontal ribs on the outside surface and straight ones on the inside, perpendicular to the others. They are coated on the outside and inside with the usual active material and are piled one above the other with the small ends down, so that each one forms a retaining cell into which the next one above is placed, leaving a thin layer of the liquid between the two; the inside of one cone forms the positive plate, and the outside of the one above, the negative plate of a cell; the cones are separated from one another by rubber rings. It is a cheap and simple form and will doubtless find considerable application for stationary purposes and small capacities and discharges. The only important objection is that if the upper edges of these conical cells become moistened with the spray, which is very likely to happen during charge, the cells will not hold their charge.

Gadot.—In the accumulators of Paul Gadot (French section, silver medal) the grid for the plates is made radically different from the usual type, as seen in Fig. 38, the first representing this new form and the second the usual form.

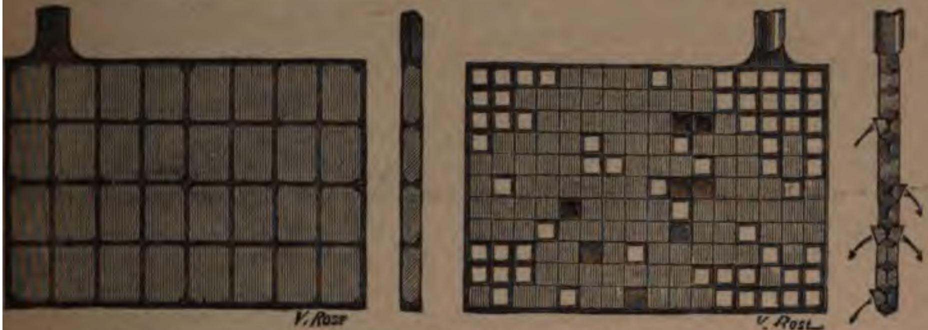


FIG. 38.—Grid for accumulator plates, by Paul Gadot; in comparison with a grid of the usual form.

It is well known that in the usual form of grids the holes or meshes are largest at the surfaces and become smaller toward the inside; the active material, therefore, having the shape something like a rivet, is thereby locked in the grid, but the force of expansion splits it through the middle and allows the two halves to drop out as shown in the figure. This is one of the chief faults of the ordinary form. To avoid this, Gadot makes the grid of two halves riveted together so that the flare of the meshes is toward the inside and not toward the outside; the active material is thereby locked in so that there is no tendency to split it, and it is almost impossible for it to fall out unless it is crushed almost to a powder. Another modification is that the meshes are made quite large, being 2 inches by ½ by ¼ inch thick. He thereby obtains much more weight of active material per pound of plates complete. He states that 48 per cent of the total weight of the plates is active material and 52 per cent is dead weight of frame. The resulting increase of capacity per pound is one of his chief claims. He gives as the normal rate of discharge 1 ampère per pound of plates, and as capacity

3.4 and 5 ampère hours per pound of plates, depending on the size. The formation is at the rate of about one-fourth of an ampère per pound, and lasts for 240 hours, including three discharges. The bar connecting all the plates of a cell consists of a horizontal bolt passing through the lug of each plate and through ferrules of lead alloy between the lugs, the whole being pressed together by nuts. This construction enables any one plate to be removed and replaced without any soldering. The results of one of the tests made for the jury were as follows: Weight of plates, 23 pounds; weight of cell, complete, 34 pounds; charge, 125.4 ampère hours at 10 ampères; discharge, 81.9 ampère hours at 10 ampères. Deductions: capacity, 3.6 ampère hours per pound; discharge, 0.44 ampères per pound; time of discharge, 8.2 hours; efficiency, 65 per cent. These accumulators are used largely in Paris for lighting purposes.

Cély.—Another accumulator of interest which is coming into use largely is that of Laurent Cély, sometimes known as the Sarcia accumulator, exhibited by the Société Anonyme pour le Travail Électrique des Métaux (French section, silver medal). It is sometimes classed under the Planté accumulators, but as the active material is made from compounds of lead, as distinguished from lead electrically oxidized, it belongs more properly to the Faure type. Their chief claim is that by their process of preparing the active material it is made extremely porous without losing its mechanical strength. The plates are made of a number of small, flat cakes of active material 1⅜ by 1⅜, by ⅜ inch thick, having rounded edges. These are placed in a mold side by side, short distances apart, into which mold is then cast melted lead alloy, which fills the interstices between these cakes, binding them all together in the form of a large flat plate three-eighths of an inch thick, having the appearance of a large grid with very large meshes. The cakes having rounded edges, are, by this process of casting the frame around them, securely fastened in their frame. In the later forms these cakes are grooved on their surface with two straight grooves into which the molten metal flows, forming an additional means of holding them and increasing their contact with the lead. The cakes of active material are made by the following process: Chloride of lead is mixed with 15 to 25 per cent of chloride of zinc; this is melted, which requires about 900° F., the zinc assisting to make it more fusible; it is then cast in an iron mold into the flat cakes of the form required; these are then washed very thoroughly to dissolve any oxychlorides, as also the zinc chloride. The density of the lead chloride which remains is from 4.16 to 3.36, depending on the per cent of chloride of zinc used. In this form the frame is then cast around a number of them as described. The plates in this form are then connected to a sheet of zinc and immersed in water acidulated with hydrochloric acid. This reduces the chloride of lead to metallic lead, the zinc being dissolved. The density of the lead cakes is then 3.09 to 2.50, and it appears to preserve the crystalline structure of the cast chloride. The density of metallic lead is 11.35, which is 3.7 to 4.5 times greater, showing the great porosity. These plates are then ready as negatives. For positives these lead plates may be oxidized by the Planté process, but they find that the peroxide is mechanically stronger if the oxidation is performed partially by chemical means. This process consists simply of heating the cakes (after reduction) in an oven in which they are converted into litharge. They are then peroxidized by the forming with a current, as usual. The peroxide obtained by this process is said to have a density of 3.57 to 2.88, that of ordinary peroxide being about 9. By density is probably meant the weight of the same volume, and is not the same as specific gravity. They claim to obtain 4.5 ampère hours per pound of plates, at a discharge rate of 0.45 ampère per pound. Their large plates are 16.5 inches square, three-eighths of an inch thick, and weigh 26½ pounds each; the large cells contain 10 negatives and 9 positives and weigh about 550 pounds, their discharging current being 250 ampères.

Huber.—In the Huber accumulator, exhibited by Cuenod Sautter & Co. (Swiss section), the plates are made in the ordinary grid form, as usual, with the additional feature that a small hole is pierced through the active material in the center of each mesh. The advantages claimed for this are that it is intended to allow for the expansion of the material, and thereby avoids all evils resulting from such expansion, such as buckling, falling out of the material, etc.; also, that it presents more surface to the action of the liquid, which enables the charging and discharging currents to be greater. Possibly, also, the active material is thereby more thoroughly utilized, giving therefore a greater capacity per pound of active material. The results of one of the tests for the jury were as follows: Weight of plates, 16.4 pounds; charge, 80 ampère hours, at 16 ampères; discharge, 64.6 ampère hours, at 10 ampères; deductions, capacity, 4 ampère hours per pound of plates: rate of discharge, 0.6 ampère per pound; time of discharge, 6.5 hours; efficiency, in ampère hours, 81 per cent.

Schoop.—In the Schoop accumulators, exhibited by the Oerlikon Company (Swiss section), the chief modification is that the whole jar and the space between the plates is filled with a mineral jelly or gelatine, called a "solid electrolyte," made by mixing soluble glass with sulphuric acid. The intention is to have it act as a porous partition between the plates, to prevent their touching by buckling or falling out of the material. It is hardly probable, however, that this soft material would not be pushed aside by the great force exerted when a plate buckles. Another improvement is, that in the large positive plates the current is led off from all four corners, and from the center of the negative plates, the intention being to avoid buckling by a more even current distribution over the plates. It is very probable that the gelatine used increases materially the internal resistance and diminishes the rate of charge and discharge.

Pollak.—For the Pollak cell, which might be classed among these, see under Planté type of cells.

OTHER TYPES OF CELLS.

Reynier.—The only other accumulators of importance exhibited and not belonging to either the Planté or Faure types were the Reynier and the copper-zinc accumulators. The Reynier is well known, consisting of zinc as a negative and peroxide as the positive plate. It has the advantage of a higher voltage, it being from 2.3 to 2.5 volts. It has such grave faults, however, that it appears to have been abandoned, and was exhibited only as a voltametric regulator, to be used in connection with a dynamo, to regulate the potential and to act as a reserve device in case of accidental stoppage of the dynamo.

Cadmium.—Another exhibitor used cadmium and tin, in place of zinc, but without apparently any great gain.

Copper-zinc.—The other accumulator, of a radically different type, is one exhibited by Elwell & Co. in the French war department, and used in the French navy. It consists of porous sheets of copper as positive plates and sheets of amalgamated tinned iron as negatives, the liquid being a concentrated solution of zincate of potash. On charging, the copper absorbs oxygen and is changed into yellow suboxide of copper; the zinc is deposited on the tinned iron; the potash is set free. They require no forming, and are said to stand any rate of charge or discharge. A set of fifty of the smaller cells was used in an experiment on a street car, and is stated to have given 45 ampères and 35 volts, making 1,575 watts for 3¼ hours, and is said to weigh 700 pounds. This would make about 100 pounds of cells per effective horse-power hour. As a good lead accumulator of the ordinary type will weigh about 110 to 120 pounds per effective horse-power hour, and even less, this new form is not much lighter than the well known forms. Their chief disadvantage is their small voltage, which is only .75 volt, or about one-third that of the lead accumulator. To be equally light for the same power it must give about three times the capacity in ampère hours per pound of plates, and even then there will be three times the number of retaining cells. It is reported, furthermore, that they do not retain their charge well and that the liquid tends to change into carbonate when in contact with the air.

This form of accumulator, slightly modified, has lately been introduced into this country, under the name of the Waddell-Entz accumulator; it is also closely allied to the Lalande & Chapron or the Edison-Lalande primary battery.

V.—ELECTRICAL MEASURING INSTRUMENTS AND 'SCIENTIFIC APPARATUS.

GENERAL.

The exhibits of the higher class of electrical measuring instruments, though confined to those of but few exhibitors, were the products of the very best makers of the world, and may therefore be considered as representative of the latest and finest apparatus of this class. There were also a number of exhibitors, who, though not ranking among the highest, had excellent exhibits of apparatus of certain classes, and specialties, such as apparatus for research, instruction, and demonstration, commercial instruments, Geissler & Crooks tubes, etc. In general, the exhibition of electrical instruments was very good and complete, representing the principal manfacturers of the world and the latest and best products.

Progress.—The progress shown was chiefly in the direction of improvements in the class of testing and measuring apparatus, the improvements being mainly to facilitate the using of such apparatus, rather than to develop new forms, though some important progress has been made in the latter direction also.

Among the more important improvements are the Deprez-d'Arsonval galvanometer, the change of the divisions in resistance boxes, the newer forms of electrometers and electrometer voltmeters, the Lippmann instruments, the Thomson ampère balance, the Wimshurst influence machine, and, in the direction of apparatus for research, that of Elihu Thomson.

Exhibits by countries.—The exhibits were confined almost entirely to France, England, and a few from the United States. Those of France were by far the largest in numbers, and, with the exception of Elliott Brothers, the most important also. In the English section there were, besides Elliott Brothers, who, with Carpentier, are the first in the world, a few very creditable exhibits. Those from the United States were limited to the apparatus for research of Elihu Thomson and Edison.

Awards.—The importance of the various exhibits may be judged from the principal awards given in this field by the jury. J. Carpentier of Paris, and Elliott Brothers of London, both received the very high award of grand prizes. Latimer Clark, Muirhead & Co. (Great Britain), and Richard Frères (Paris) received gold medals. Dalloz, Gillet et Guyot-Sionnet, Gaiffe et Fils, and Patterson & Cooper received silver medals. Besides these, Breguet was "hors concours," being represented on the jury, and Ducretet was classed in the section of instruments of precision in which he received a grand prize.

Classification.—In the accompanying detailed description, the exhibits are described in the following order: galvanometers, electrodynamometers, electrometers, resistance boxes, ampère and volt meters, meters, and miscellaneous apparatus. As most of the apparatus is already well known in a general way, no attempt is made here to give a thorough description, a familiarity with the well-known apparatus being assumed. The description is confined merely to a summary of such points as are of interest because of their novelty or of their importance, or of their recent development. Apparatus for demonstration and instruction has not been included, as it has undergone little recent development.

GALVANOMETERS.

Elements.—To facilitate the description of galvanometers they may be considered as consisting in general of three essential elements, namely: first, the part through which the current to be measured passes, usually in the form of a coil of many turns of wire, with the object of multiplying or magnifying the effect, which it does in proportion to the number of turns in the coil; second, a light movable part which is moved by and in proportion to the magnetic force exerted by the current in the coil; third, a directing force which gives the movable part direction and antagonizes the force exerted by the current, so that the resultant of the two will indicate the measure of the current. In the ordinary well-known galvanometers the coil is fixed and must be placed with its axis east and west; the movable part is a small light magnet suspended on a fiber without torsion, or on a pivot, and the directing force is the magnetism of the earth which tends to hold the magnet north and south.

Definition of terms: Constant.—The following are the principal terms used in connection with galvanometers to indicate their properties, such as the currents for which they are to be used, etc. The "*figure of merit*" of a galvanometer indicates what is usually referred to as its sensitiveness; that is, it is a constant which indicates how small a current can be measured with the galvanometer; it therefore gives a number by which different galvanometers may be compared with each other in this respect, provided the same unit of deflection has been used. The *figure of merit* is defined as the reciprocal of the current which will produce one unit deflection on the scale. A high figure of merit therefore shows that the galvanometer will measure very small currents; that is, it is very sensitive. For this the French use the better term "*constant*" of a galvanometer, which is defined as the resistance, usually in megohms, through which one volt will produce one unit deflection. It may readily be shown that the two terms are absolutely the same; that is, that the *figure of merit* really is this resistance which is called the *constant*. The two terms may therefore be used interchangeably. This constant is readily obtained for any galvanometer in which the deflections are practically proportional, as follows: Connect a battery to the galvanometer through a resistance, and read the deflection, usually in millimeters; divide the total resistance by the electromotive force and multiply by the deflection; the result is the required constant or figure of merit in ohms; if galvanometer shunts have been used, the correction must be made. In a large tangent galvanometer the constant is usually that current which deflects it 45 degrees; this is the reciprocal of the other constant; the unit of deflection, however, is different, so that no comparison can be made, except with other tangent galvanometers.

Aperiodic.—*Aperiodic* is synonymous with the term *dead beat* and means that the movable part of a galvanometer comes to rest quickly without oscillating to and fro a number of times, be it when it is deflected or when it returns to zero. In a certain class of galvanometers which are aperiodic only when the circuit is closed, the *limit of aperiodicity* is the greatest resistance in the external circuit with which they will be aperiodic when returning to zero; that is, when the pointer will not pass by the zero on returning to rest.

Ballistic.—A *ballistic* galvanometer is one in which the moving part has considerable inertia; it is used for measuring momentary currents, the principle being that the moving part does not begin to move until the momentary current has ceased; the deflection is then a mere single oscillation. Strictly speaking it measures coulombs, and not ampères.

Astatic.—An *astatic* galvanometer is one in which the directing force of the earth's magnetism is made exceedingly small by having two needles connected on the same spindle, and turned in opposite directions, so that only the difference of their directing force acts while the current acts on their sum, thereby increasing the relative power of the current.

Exhibits.—The objects of improvements exhibited are, variously, to increase the constants or figure or merit; to increase the aperiodicity; to make them independent of the magnetic field of the earth, dynamos, moving iron masses, etc.; to make them less delicate to handle, and to simplify and cheapen their construction.

Thomson's galvanometer.—The well-known Thomson single-coil and double-coil astatic galvanometers were exhibited by Elliott Brothers, of London, their original makers, who do not appear to have modified them any; they are too well known to require description here.

Carpentier's modification.—Carpentier exhibited a modification, the object of which is to make all the parts readily accessible, and also to enable the coils to be changed, all of which is done with merely a few thumb screws.

Fig. 39 shows the galvanometer complete. The plate glass faces can be pulled out from the top; by unscrewing the two thumb screws B B, the front plate, shown in Fig. 40, containing the front halves of the two coils, can be removed, leaving the needle spindle, with the mirror, damper, and suspension exposed, as seen in Fig. 41, allowing any adjusting and repairing to be made. The bolts and nuts BB′ are so arranged and insulated with ivory that the act of screwing on the plate (Fig. 40) makes all the connections required. The rear plate may be removed similarly, and both may be replaced by other coils of a different resistance. The little lozenge-shaped air damper also prevents the spindle from making a complete revolution. The form is a very practical one, and is an important improvement on the original form. The following are some of the dimensions and constants of the most sensitive one made: Coils,

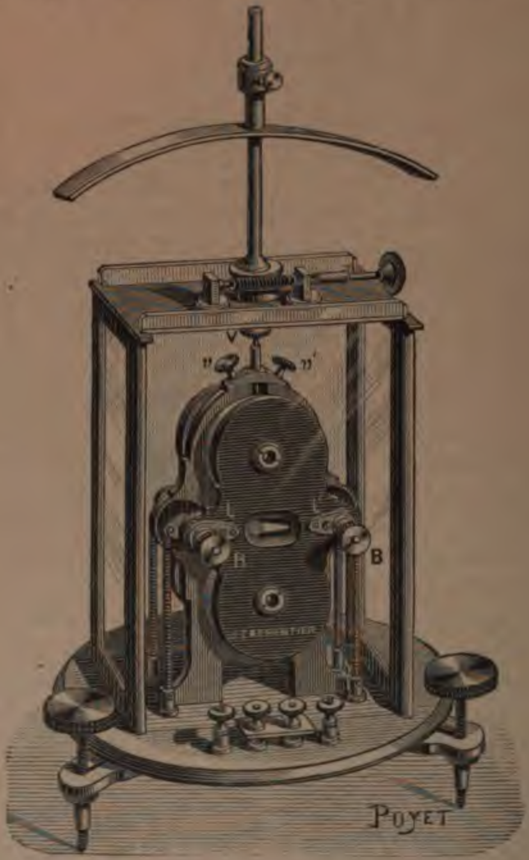


FIG. 39.—Modified Thomson galvanometer; by Carpentier, France.

60,300 turns of wire one-tenth of a millimeter diameter, about No. 38 American gauge; resistance, 16,130 ohms. The constants vary according to the position of the directing magnet on the top. The time of an oscillation in coming to rest will increase with the constant, but not in as rapid proportion. For constants of 800, 1,600, and 15,000 megohms per millimeter deflection, the time of a single oscillation was 4¼, 7, and 21 seconds, respectively. Distance of scale, 1.1 meter.

CARPENTIER'S THOMSON GALVANOMETER.

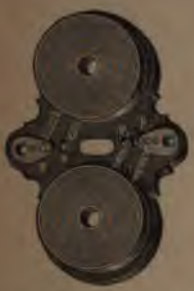


FIG. 40.—Front plate, carrying halves of the coils.

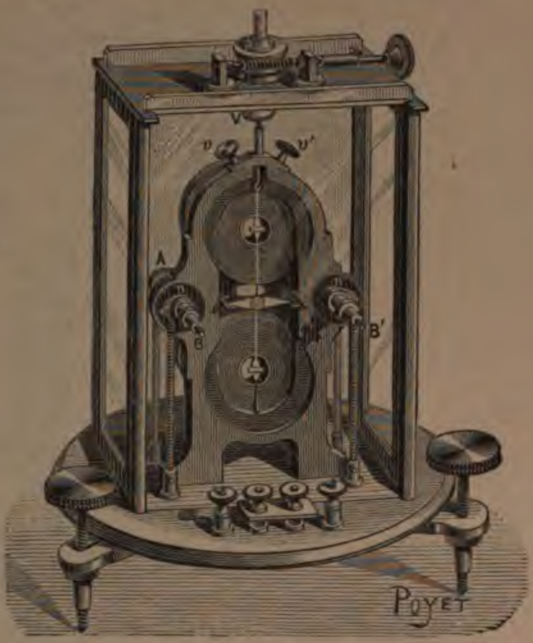


FIG. 41.—The galvanometer with the front plate removed.

Deprez-d'Arsonval.—The most important and interesting exhibit of galvanometers was unquestionably that of the so-called Deprez-d'Arsonval galvanometer, made and exhibited by Carpentier, of Paris. This instrument is so simple and eminently practical, and has such excellent qualities that it will doubtless replace most of the other forms of galvanometers, besides creating new uses in places where the older forms could not be used on account of their being affected by so many surrounding conditions. It is already in use very largely in France, and it would doubtless meet with the same favor in the United States. The principle is essentially the same as that used in the well-known Weston instruments.

Principle.—The galvanometer consists, as shown in Fig. 42, of a U-shaped magnet, having a small cylindrical piece of soft iron between its poles, secured by means of a standard in the rear. The small, light coil of wire is wound around a small, open, rectangular frame, and is suspended as shown so that it can revolve freely around the suspension as an axis, the two long sides of the coil moving in the most intense parts of the field. The suspension wires are the leads to and from the coil. The current to be measured passes through the coil and tends to revolve it, precisely as if it were the armature of a small motor. The suspension wires are soldered at their ends, and their torsion acts to give the coil direction and to antagonize the force exerted by the current; the upper one can be twisted slightly to set the coil to zero. The order of things in the ordinary galvanometer is, therefore, reversed; instead of having a large, fixed coil and a small, light, movable magnet, the coil is here made light and movable, while the magnet is large and fixed, the weak and variable earth's magnetic force being replaced by the reliable and invariable torsional force of a wire. In any galvanometer, the deflecting force is proportional to the product of the magnetism of the coil and the magnet; in the old form of galvanometers, the former is great and the latter is necessarily small; in the present form it is just the reverse, the magnets being made very powerful.

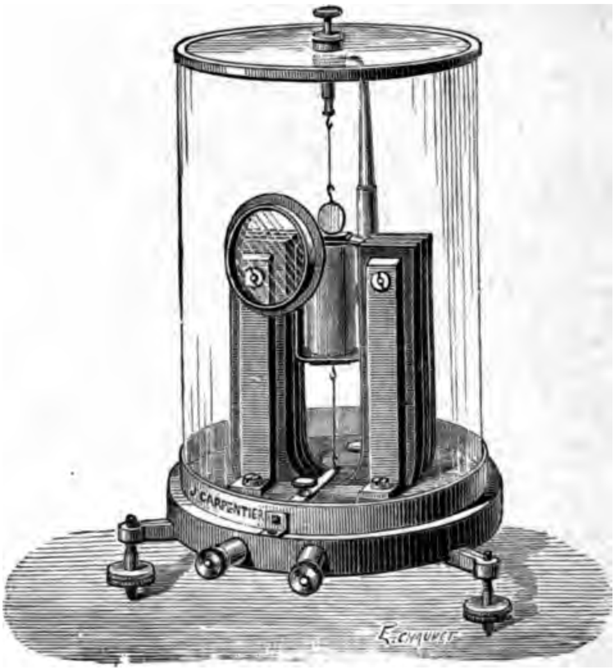


FIG. 42.—Deprez-d'Arsonval galvanometer.

Historical.—The idea of this disposition is not new, it having been suggested by Maxwell and used by Sir William Thomson in his syphon recorder, but we believe that it was not until 1880 that it was applied to commercial galvanometers by Dr. d'Arsonval. The same principle is applied, at present, in a more compact form here in the United States in the Weston commercial volt meters and ampèremeters.

Properties and advantages.—Among the chief advantages, besides simplicity, are that it is aperiodic or deadbeat, and that it is independent of the earth's magnetism or that of surrounding bodies. The field produced by the magnets is so intense that the earth's magnetism is practically nothing compared to it, and even the presence of dynamos and other magnets or moving masses of iron have practically no effect on the deflections.

The aperiodicity is due to the fact that the movement of the coil when deflected generates a counter electromotive force which tends to reduce the original, the result being that the pointer or spot of light will move slower and slower as it approaches its point of rest, and will not pass it and oscillate. In the same way it will come to rest at its zero, provided that the galvanometer is short-circuited so as to allow the current, which is generated by the moving coil, to flow, and thereby to oppose the motion. This aperiodicity is not only a great saving of time, but enables the galvanometer to be used when instantaneous readings must be taken, and when, therefore, the ordinary galvanometers can not be used.

The sensitiveness or figure of merit increases with the magnetism of the magnets, with the number of windings on the coil, and with the length of the suspension wires: it diminishes as the suspension wire is larger. For the same coil and magnets the figure of merit may be varied by merely changing the size of the suspension wires. It can be used with shunts, as any ordinary galvanometer. If used with a spot of light and ordinary scale, the deflections are proportional to the current. The zero point depends only on the suspension wires and therefore remains fixed if they remain unchanged. The same figure of merit or constant can be obtained with a much less resistance of wire than in the ordinary galvanometers, being equivalent therefore to a low-resistance galvanometer with a high figure of merit or constant.

Even the most sensitive forms, however, do not equal the figure of merit of the double astatic Thomson galvanometer.

Constants.—In the form used most frequently, shown in the above figure, the coil has about 200 ohms resistance, the suspension wires are of silver, fifteen one-hundredths of a millimeter, or about 0.006 inch (No. 34) diameter, and each about 2 inches long; the constants vary from one to four megohms, and the limit of aperiodicity is about 500 to 600 ohms, that is, when short-circuited through this resistance (or anything less), it will not pass by the zero in moving back after having been deflected. The transparent scale is usually half a meter long, graduated in millimeters, and is placed at a distance of one meter. The tenths of a millimeter can readily be estimated, and correspond to a deflection of the coil of 10 seconds or one three hundred and sixtieth of a degree.

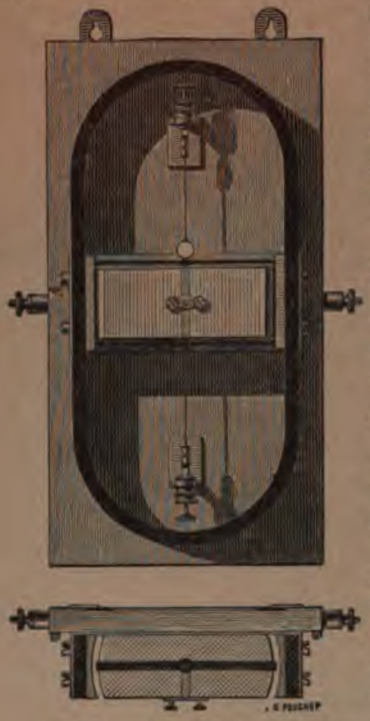


Fig. 43.—Ballistic galvanometer.

Modifications; ballistic—There were exhibited many modifications in details for special purposes. Fig. 43 shows the form used for a ballistic galvanometer. The coil is made very large and with its greatest dimension perpendicular to its axis, to increase its inertia. The two U-shaped magnets, with their like poles together as shown, form the outside of the galvanometer. The coil is 50 by 64 millimeters and is composed of 500 turns of one-tenth of a millimeter wire, having a resistance of 500 ohms. The suspension is by means of silver wires of one-tenth of a millimeter and 70 millimeters in length. The constant is 100 megohms. It gives forty-three divisions for a discharge of a micro-coulomb. Its limit of aperiodicity is about 6,000 ohms, which is exceedingly high. When allowed to oscillate freely its period of oscillation is about 6 seconds, while when short-circuited it requires 4 minutes to return to zero, the aperiodicity is so great; by properly timing the moment of this short circuit, this time can evidently be reduced to a few seconds only; this overcomes the objections to ordinary ballistic galvanometers, in which the needle requires a long time to come to rest. It is claimed that it will measure correctly momentary currents, even if their duration is several seconds, as in the case of large dynamo field magnets.

Proportional direct reading.—To obtain a direct reading galvanometer with proportional readings, used chiefly for medical purposes, and graduated in milliampères, a modification of Figure 42 is used. One pole of the magnet is connected directly to the cylindrical iron core, which, in this case, is hollow; the other is connected to an open cylinder of iron encircling this first pole, leaving an annular space between them, which forms the single field. The rectangular coil is suspended so as to turn on one of its sides as an axis, and not in the field, while the other moves in this annular field. The deflections are through an angle of 180°, and are sufficiently proportional, varying only 2 per cent. They are made to correspond to milliampères by an adjustable shunt coil. For an illustration and description see La Lumière Électrique, May 11, 1889, p. 270.

Sensitive form.—If the coil is held at top and bottom by two thin and long wires it is too apt to tremble. To obviate this the coil is for such purposes suspended by a single long thin wire from the top only, while the other connection is made by a platinum wire at the bottom dipping into a mercury cup; the mercury is covered with a solution of cyanide of potassium to dissolve the film of oxide formed whose viscosity would affect the free motion of the platinum wire. The constant of this is 125 megohms per millimeter deflection; even this however does not compare with the best Thomson, whose constants are as high as 15,000 to 16,000 megohms per millimeter. When zero methods alone are used the magnets may be electromagnets and the field thereby increased considerably, increasing the figure of merit.

Other modifications.—It is made also in the form of a differential galvanometer, the coil being wound double, and the suspension being bifilar both at top and bottom. The difficulty in any differential galvanometer is to have the action of the two coils absolutely the same, so that if the same current be passed through both, in series but in opposite directions, there should be no deflection; the difference found in one of these was only one seven-hundredth, which is exceedingly small. For absolute proportionality to the current in any of these galvanometers the upper suspension is so arranged that it can be turned so as to bring the coil back to zero for every deflection. The angles of torsion are then absolutely proportional. When it is desired to have several spools of a different number of turns and different constants for the same galvanometer they are arranged with each one on its own standard, so that all that is necessary is to change the whole standard, which requires but a moment, the connections being made by the act of fastening the standard. The sensitiveness may also be changed by raising, more or less, the whole standard with its coil, thereby bringing less of the coil into the field. In a form used for measuring heat, the coil itself is a single, short-circuited, thermal couple suspended on a cocoon fiber. The heat to be measured is radiated upon one junction, the other being covered by the mirror. The couple is held in direction by a small piece of iron wire fastened to it.

Claude form.—The above were all made and exhibited by Carpentier. A few other makers also exhibited this form, among which was one exhibited by F. A. Claude (French section) as a relay for a particular system of telegraphy in which the relay must operate for widely differing currents. The single magnet was flat; the coil was a flat ring, in the plane of the magnet and revolving on its diameter, which was perpendicular to the lines of force. A fixed, flat, circular disk of iron inside of the coil increased the intensity of the field; the whole formed a very compact and simple apparatus.

Deprez galvanometer.—Another very simple and convenient galvanometer also exhibited by Carpentier was that known as the Deprez or the "fish bone" galvanometer. It consists of a magnet, as seen in Fig. 44, a fixed coil in the same plane with it, and a small flat piece of soft iron pivoted so as to turn on its axis inside of the coil and between the magnets. This iron is usually cut on its outer edges, resembling somewhat the backbone of a fish, from which its name. When a current passes through the coil the field produced, being perpendicular to that of the magnets, changes the direction of the resultant lines of force, and thereby deflects the iron piece. Its advantages are that it is portable and exceedingly simple; the deflecting forces are comparatively great, its action being therefore quick and decided. The deflections are, however, not at all proportional. It is particularly applicable when a decided and definite deflection is required, as, for instance, in a maximum and minimum volt indicator exhibited, in which a pointer attached to the iron piece moved between two platinum contact points quite close together, so that if the deflection changes one or the other of these contacts would be closed, ringing an alarm. The deflection is opposed by an adjustable torsional spring, by which it can be set to the required number of volts. Its accuracy is said to be within 1 per cent. Another form

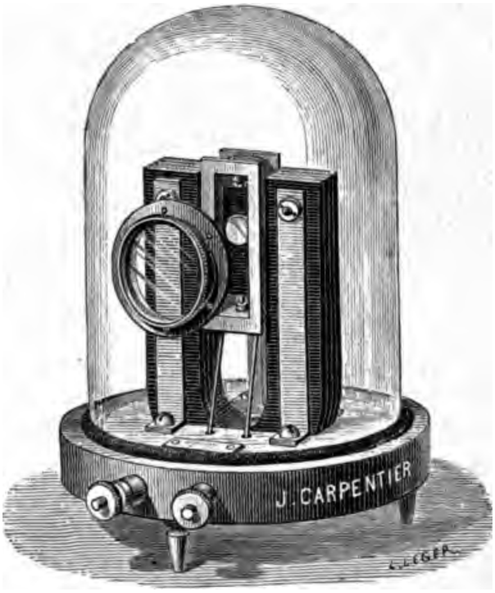


Fig. 44.—Deprez's galvanometer.

of this galvanometer exhibited is used by the municipal authorities in Paris to test the leakage from the incandescent mains. It is portable and conveniently arranged in a closed box, with a small reading telescope having the scale in the inside.

Wiedemann galvanometer.—Branville exhibited a galvanometer of the Wiedemann type, devised by d'Arsonval, the most important novelty of which is that the needle with its mirror, copper damper, and suspension are all in one tubular piece, which can be readily removed and the needle or suspension examined without any alteration in the adjustments of the galvanometer.

Heat galvanometer.—Edison exhibited a deadbeat galvanometer similar in principle to the well-known Cardew voltmeter, and which it is claimed antedates the latter, having been invented in 1880. It consists of a long fine platinum-iridium wire, one end of which is secured and the other is wound around a small shaft, which therefore rotates as the wire expands and contracts by the heat of the current passed through the wire. A spiral spring opposes the pull of the wire, and a mirror on the shaft indicates the deflections by means of a spot of light; the whole is inclosed in a glass tube through which the terminals are fused and from which the air has been exhausted.

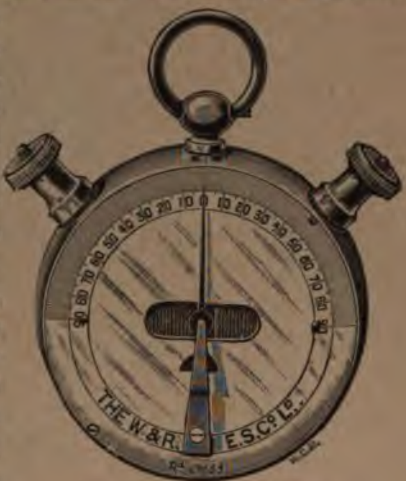


Fig. 45.—Pocket galvanometer.

Pocket galvanometer.—Messrs. Woodhouse & Rawson (French section) exhibited a very convenient form of pocket galvanometer having the external appearance of a watch, as shown in Fig. 45, which explains itself. The needle is balanced and pivoted with two pivots, and the field is doubtless an artificial one of a permanent magnet.

Accessories; scale.—Among the accessories appertaining to galvanometers were a few exhibited by Carpentier, which are of interest.

The scale almost universally used with all his reflecting galvanometers, shown in Fig. 46, is of translucent celluloid, supported on an extension stand with a weighted base. It is always graduated in millimeters, and is usually 50 centimeters long, with the zero at one end, instead of in the middle as usual with the English Thomson instruments. This single-scale system enables readings to be taken over the whole length of the scale, and also enables all deflections to the right or left to be taken without setting to zero every time, the subtraction necessary in this case being often less troublesome than setting for zero in a double scale. If the same deflection is to be taken to both right and left, to get their mean, it is less troublesome, because in that case no zero reading need be taken at all. This system of single scale seems to be used almost exclusively in both France and Germany in place of the double scale or central zero scale used largely in England. In the figure the little square window with its cross hair, in the screen below the scale, admits a beam of light of that cross section reflected from the mirror, which has a universal move-

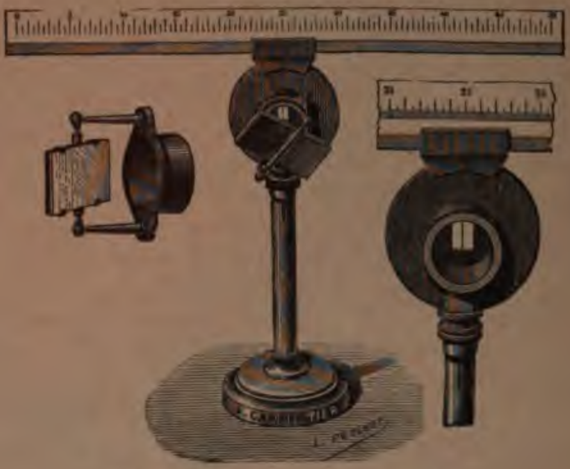


Fig. 46.—Celluloid galvanometer scale.

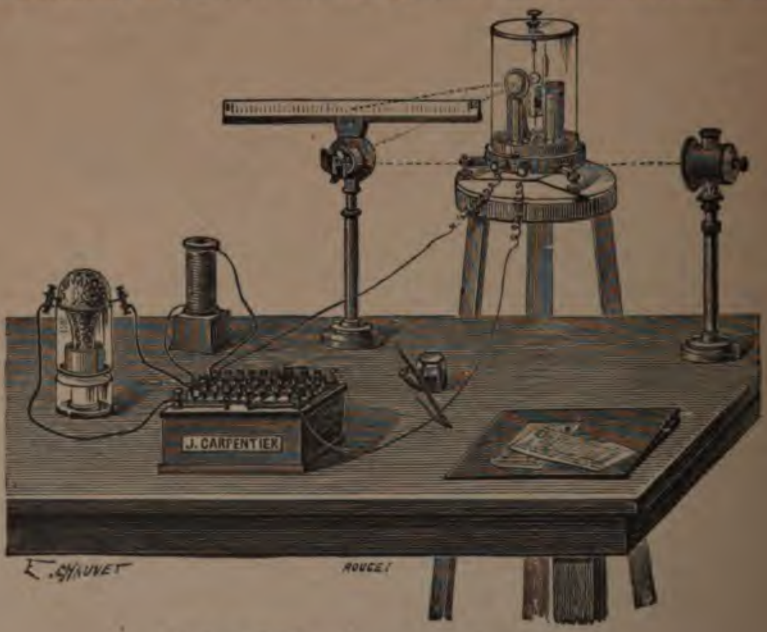


Fig. 47.—Reflecting galvanometer outfit; Carpentier.

ment; this beam of light is seen on the scale in the form of a large, bright, square, spot, and can therefore be found or followed quite readily. The sharp, black line through the center enables the reading to be taken with precision. A lamp light, and even a dark room, though preferable, are not necessary, as the light from a window, reflected by the mirror, is sufficiently bright to enable the spot of light to be seen even if the room is not darkened. The complete galvanometer outfit in its simplicity is seen in Fig. 47. As a source of light, the spring candlestick shown, with a flame fixed in position and surrounded by a proper reflector, is an excellent substitute for the objectionable lamp. The brass plate under the galvanometer, with three radial grooves, enables the galvanometer to be insulated and cushioned with rubber, while its position is determined by the grooves, so that it can always be put back into exactly the same position after having been removed.

In the Mudford modification of the scale exhibited by Patterson and Cooper, in the British section, the cross wire is placed between the condensing lens and the galvanometer, so as not to be magnified by this lens. This is claimed to give a much sharper and finer image of this line on the scale than if the wire were placed on the other side of the lens.

Novel desk outfit.—A somewhat novel disposition was shown, but we fail to see its advantage except to save space and to protect the galvanometer. The galvanometer is placed in the bottom of the table or desk, the beam of light being reflected upward by means of a reflecting prism. The scale lies flat on the desk over the galvanometer, and a long, narrow mirror at an angle of 45° over it makes it appear to be upright, so that it is seen just as usual.

Portable outfit.—In another form, a very convenient and compact portable outfit, the galvanometer is in a box through one side of which a small reading telescope is introduced close to the mirror, having a microscopic scale of 120 divisions in the inside near the eyepiece, which is magnified so as to be almost as large as a millimeter scale. An adjustable window, with a cross hair on the neighboring side of the box, and a small adjustable reflector of white paper, illuminates the whole field of the telescope and shows a black line, which can be sharply focused by the telescope.

ELECTRO-DYNAMOMETERS.

General.—Electro-dynamometers, which measure the relative force between two currents, have lately come into use largely in meters for measuring and registering the quantity of electric energy supplied to a purchaser. The electro-dynamometer is used in these meters in order to take into account both the volts and the ampères delivered, by indicating or measuring their product—that is, the watts, for which reason they are often, and correctly, called "watt meters." For a description of those used in meters, see under the heading "Meters."

Thomson balances.—The Thomson electric balances, which are also electro-dynamometers, were not exhibited, but they will be mentioned under the heading "Ampère meters."

For telephone currents.—The French Telephone Company exhibited a small electro-dynamometer for measuring the very small currents in a telephone. It consisted of two small, vertical, circular coils of three-fourths of an inch diameter, one was fixed and the other was movable, being attached to the end of a small horizontal lever of 1½ inches length, which was suspended by a single cocoon fiber so as to turn about this as an axis. Contacts to and from it were made by wires dipping into mercury. The torsional force of the fiber opposed the repelling force of the two coils and thereby indicated the strength of the current.

ELECTROMETERS.

General.—Electrometers appear to be coming into use gradually, in practice, as distinguished from scientific research. Their undoubted superiority in certain special cases is being appreciated more and more, as, for instance, for alternating potentials, for very high potentials, or for measuring potentials without causing a current to flow. The direction of improvement has therefore been to construct them in as practical form as possible, rather than to try to improve the general principle of their action, which latter has remained absolutely the same as Thomson's original suggestion, namely, the lateral attraction of two electrified plates to a third one, moving between them and electrified oppositely. They are already used in a very simple form as commercial voltmeters for high potentials above 500 volts, such as in arc-light circuits.

Carpentier's form.—One of the most important improvements shown was in the form exhibited by Carpentier. The directing and deflecting forces in an electrometer being necessarily very small, the needle in the usual forms will oscillate very slowly and for a long time, which is very objectionable and often prohibits the use of the instrument. The object of the present construction is to overcome this and to make it aperiodic. This is done by developing an intense magnetic field in the space through which the movable part oscillates. This develops Foucault currents in the moving parts, which oppose and check its movement without in the slightest way affecting the deflection. The form of the instrument is seen in Fig. 48, and resembles somewhat in external appearance the Deprez-d'Arsonval galvanometer described above (Fig. 42). The electrified quadrants of the electrometer are made in the form of a cylinder, split longitudinally into four parts, a form adopted a number of years ago by Edelmann, of Munich. A similar split cylinder is in the inside and concentric with it. The movable part is in the form of a light rectangular metallic frame, like a shallow box without top or bottom, and is usually made of aluminum. It is suspended by torsion wires, as seen, so that it can revolve, its long slides moving through the annular space between the quadrants. The quadrants and movable frame are electrified, as usual, either by the potential which is to be measured or by means of a high potential battery in addition. In the former the deflections are proportional to the square of the potential; in the latter they are simply proportional to the potential. The torsion of the suspension is the opposing force; the magnets are merely for making the movement aperiodic, and have no other function; they therefore do not affect the constant. The most delicate form is said to give a deflection of 3 millimeters for 1 volt with a 100-volt charging battery, and 25 centimeters for 70 volts without a charging battery. The same form, except that the cylinder is horizontal and the counterforce gravity, is made in the form of a volt-meter, which see under that heading. These are made up to 3,000 volts.

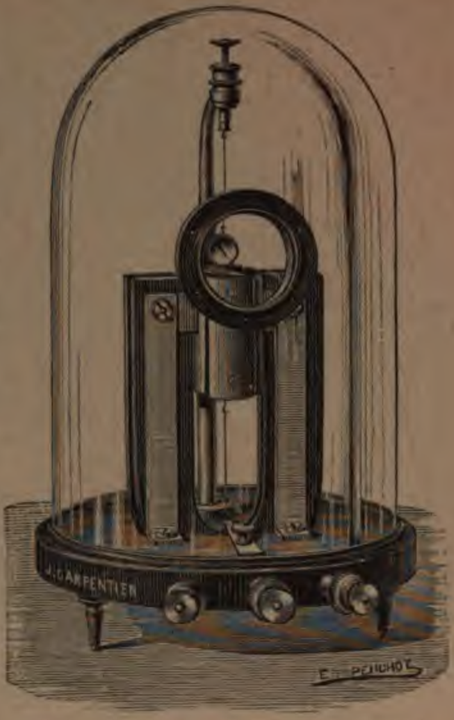


FIG. 48.—Carpenteir's quadrant electrometer.

Mascart's form.—Another electrometer, exhibited by Carpentier, was one devised by Mascart. It is in general like the well-known Thomson quadrant electrometer, but is modified in details of construction so as to bring it into a more practical form. It is principally for laboratory purposes, and is used chiefly for measuring atmospheric electrification.

Blondlot & Curie form.—Another form of some interest is that devised by Messrs. Blondlot & Curie, and exhibited by Ducretet (French section). It is somewhat like the Thomson form, except that it has only two sets of "quadrants," instead of four, in this case in the form of two semicircles. The "figure-8" needle is replaced by a round, light disk of aluminum, also cut into two semicircles, and moving between the upper and lower plates of the semicircles. These fixed semicircles are magnets, so as to act at the same time as dampers, to make the motion aperiodic. The central moving plate is suspended by long torsion wires, one-fiftieth millimeter in diameter, as in the Carpentier form, acting also as leads. It may be used with or without a charging battery. In the former case the two halves of the moving part are connected to the charging battery and the others to the unknown potential; in the latter case the semicircles are connected in pairs. For further description, see La Lumière Électrique, October 23, 1886.

Lippmann capillary form.—Bréguet and Ducretet both exhibited the Lippmann capillary electrometer, which appears to be coming into use gradually. It is limited in its application, but is a very good instrument in its field; that is, to measure potentials less than one volt down to one ten-thousandths of a volt. Its principle is that the surface of contact between mercury and acidulated water in a capillary tube will change its place in the tube when the two liquids are electrified. Readings are made with a microscope. It is prompt and aperiodic, and is said to be used in anatomical researches to measure the variation of electrification accompanying muscular contractions. It is used in electrical laboratories for standardizing by certain methods in which only very small differences between two potential measurements are to be detected or measured. For a further description, see Traité d'électricité, Vol. 2, by Mascart.

Voltmeters.—For electrometers which are arranged as commercial voltmeters, see under that heading.

RESISTANCE BOXES.

General.—Resistance boxes were exhibited by many makers, but the finest were unquestionably those of Elliott Brothers, of London, and of Carpentier, of Paris. With the exception of the improvements noted below, there was little to be described. Legal ohms are adopted universally by French makers, while English makers still use the B. A. unit largely, though all Elliott coils are made for either. German-silver wire is still used almost entirely for the French coils, while the Elliott coils are made largely of platinum silver alloy, which has a lower temperature coefficient.

Division of coils.—One of the principal modifications which appears to be coming into use and replacing the older form is shown in the Elliott box, Fig. 49.

The coils are arranged in groups, each of ten equal coils, one group of units, one of tens, etc. This very greatly facilitates plugging and avoids errors in readings; it has the additional feature that the number of plug contacts (four in this box), and therefore their resistance, is always the same, which is not the case in the old form, in which the number varies with every resistance unplugged. On the other hand, it increases both the size and the price of the box, as there must necessarily be two and a half times as many coils (as ten is to four) for the same range of resistance. In another box of Elliott, Fig. 50, the adjusting is even more convenient and rapid, by means of the levers and sliding contacts shown.

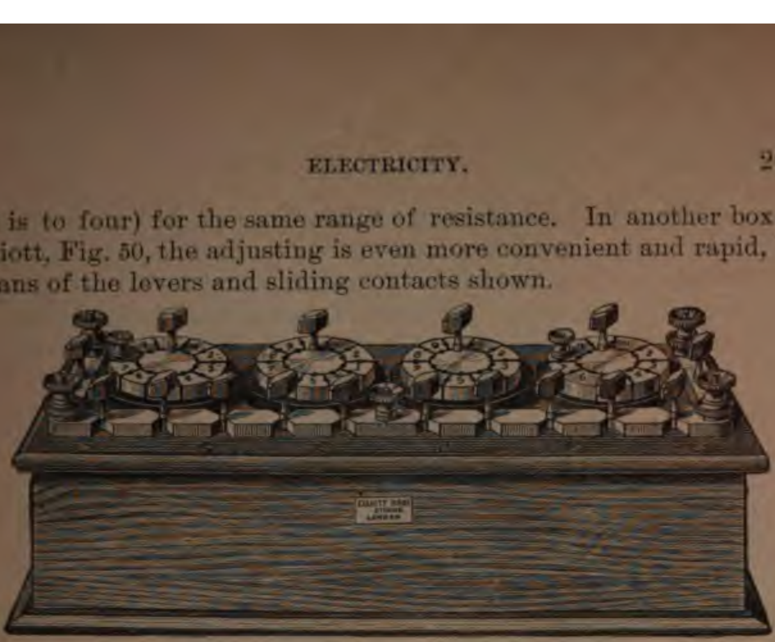


Fig. 49.—Resistance box with plugs; Elliott Bros.

These contacts are so arranged that they make contact with the next coil before they leave the previous one, so as not to open the circuit; one revolution on one box corresponds to one step on the next. Bréguet exhibited one similar to this, with the additional

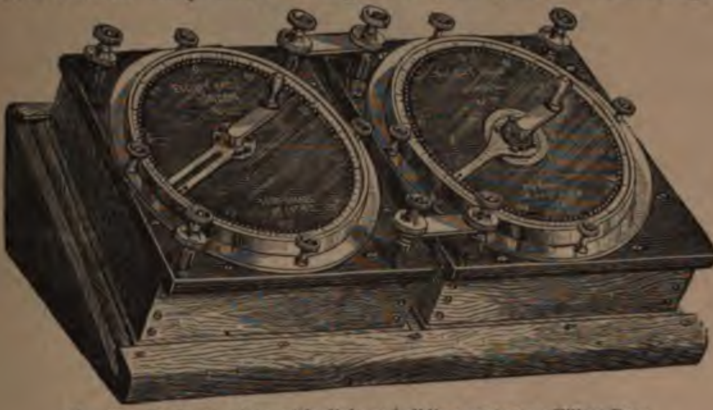


Fig. 50.—Resistance box with dials and sliding contacts; Elliott Bros.

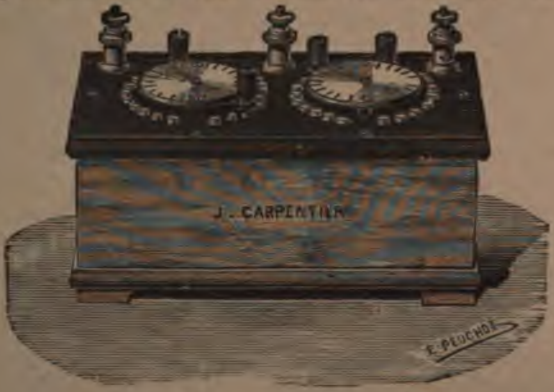


Fig. 51.—Carpentier's dial resistance box.

feature that every complete revolution of the right-hand lever will move the left-hand one forward one step. In the Carpentier box, Fig. 51, the same arrangement as in Fig. 50, is modified so as to have four groups, namely, units, tens, hundreds, and thousands, of ten each, arranged in four semicircles, and with four levers; this is not quite as convenient, but is much more compact, as there are only forty coils, while in the other, Fig. 50, there are two hundred for the same range and degree of adjustment. All these are less reliable and accurate for very exact work.

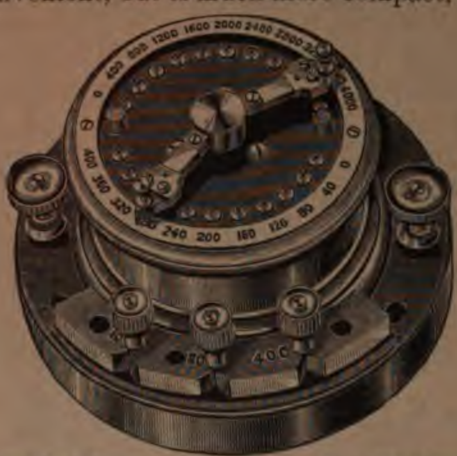


FIG. 52.—Compact form of resistance box; Elliott Bros.

A somewhat similar but much more compact form, made by Elliott, is shown in Fig. 52, and is used exclusively for telegraph work, chiefly for balancing a duplex system. Edison exhibited one for a similar purpose consisting of disks of silk, saturated with a sizing mixed with plumbago, which after being dried are placed over one another forming a pile which is compressed by a screw with a divided head.

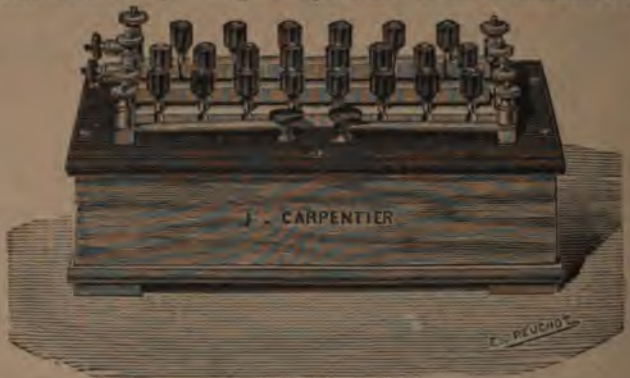


FIG. 53.—Carpentier's resistance box with plugs.

Plug heads of the form shown in Fig. 53 have replaced the old lozenge form altogether in the Carpentier boxes. They are much more convenient, and do not break like the old form, which is very weak in the middle; they have the additional advantage that in plugging, in a compact box, one is not so apt to loosen the neighboring plugs by accidental pressure from the fingers. Another improvement noticed was that the boxes were sometimes accompanied by plugs fitted with a binding screw at the top, to enable a wire to be connected to any special one of the coils.

Legal ohms.—Carpentier (who is the maker of the French national standard ohm) exhibited standard ohms in various forms, including mercury ohms in glass tubes. In connection with standard ohms he exhibited also a large, massive Wheatstone bridge for comparison of standard ohms.

Artificial lines.—Latimer Clark, Muirhead & Co. exhibited their combined resistance coils and condensers, the object of which is to make adjustable artificial lines, having both capacity and resistance combined in proportion to their length. They are made of strips of tin foil which are so proportioned in size and so wound that they have both capacity and resistance in the same ratio as the lines with which they are to be used. The transatlantic cables are duplexed with these artificial lines.

AMPÈREMETERS AND VOLTMETERS.

The number of different systems of ampèremeters and voltmeters exhibited was about as great as the number of electric lighting companies and instrument makers combined; each one had his own system. Most of them appeared to be sufficiently good as ordinary commercial apparatus, the purpose for which they were intended, but few deserved to be ranked among reliable and accurate measuring instruments. The underlying principle of most of them was the electro-magnetic action of the current through a coil of wire on a piece of iron or on a magnet. A few of the more important ones will be mentioned below. The only ones differing radically were the Lippmann mercury ampèremeter, the Cardew voltmeter, and the Edison volt indicator, which is on the principle of a Wheatstone bridge, and the volt meters on the electrometer principle. The introduction of the latter, in a practical form, was the most important improvement in voltmeters. The most important ampèremeter for accuracy, reliability, and constancy is unquestionably the Thomson balance, which was not exhibited. Almost the same may be said of the Weston voltmeter, which was not exhibited either. All but direct reading instruments seem to have gone out of use.

Deprez-Carpentier.—Among the ordinary commercial forms not differing essentially in their general principle may be mentioned the following: The one meeting with most general favor, judging from the frequency with which one sees it used in France, is the form known as the Deprez-Carpentier, and exhibited by Carpentier. It is merely a sort of galvanometer with an artificial field; that is, it consists of a soft iron pivoted needle under the combined action of a magnet and coil, placed with its axis slightly inclined to the usual position perpendicular to the field, to obtain a better deflection. They are arranged in a neat, convenient form, and are comparatively cheap, costing only $10. The ampèremeters may be supplied with conveniently arranged "reducers" (that is, shunts), which increase in a fixed proportion the value of the readings. Similarly the voltmeters may be supplied with an extra resistance (in series) to increase the value of their readings.

Desruelles.—In the form exhibited by Desruelles the needle is in the form of a small flat piece of soft iron pivoted so as to move like a weather vane or a flag against the action of a spring. It moves in a cylindrical space in a coil, which is lined with a thin sheet of soft iron in the shape of an isosceles triangle bent around so that its apex almost meets the base. The attraction of the needle to the constantly increasing amount of iron opposite to the end of it gives a nearly proportional deflection through almost 180 degrees. They are of interest on account of their cheapness.

Patterson and Cooper.—Among the exhibits of Patterson and Cooper were the well known original Ayrton and Perry voltmeters and ammeters, which are merely galvanometers with an artificial field and a double-pivoted needle; one form of these is arranged with a commutator attachment so that it can be recalibrated with a standard cell. They also exhibited an ampèremeter or "engine-room indicator" for large currents, consisting merely of a small magnetic needle pivoted on horizontal pivots and weighted so as to give it a direction parallel and quite near to a thick bar of copper through which the current flows; the direct action of this current deflects the needle against the action of gravity; the counterweight is adjustable, enabling the readings to be varied; in another form it is replaced by a spring. One of these was shown as a registering instrument, chiefly for central-station work. The same makers also exhibited a small pocket voltmeter of the permanent magnet type, having the outside appearance and size of a pocket watch and weighing 6 ounces.

Cardew.—The same makers exhibited the well-known Cardew voltmeters, in which the heating of a stretched wire by the current measures the current. They are too well known to require description here. In the later form the fine, stretched platinum silver wire of .0025 inch diameter is heated by the current for many days before calibration, to insure its remaining constant. The wire is protected by a very fine platinum wire fuse. They are usually made for 120 volts, reading through 360 degrees of the dial, and are one of the few voltmeters which are applicable alike for continuous and for alternating currents, and which can be left in circuit continuously.

Ayrton and Perry spring instruments.—Messrs. Latimer, Clark, Muirhead & Co. exhibited the well-known Ayrton and Perry spring instruments, in which the underlying principle is that a small axial pull of a solenoid on a special form of spring will result in a greatly increased rotary motion of the end of this spring. The spring consists of a helix made of a flat band of steel rolled around a long cylinder.

Alioth.—Messrs. Alioth & Co. (Swiss section) exhibited ampère and volt meters, in which a curved core was sucked into a curved solenoid. The construction is quite similar in principle to the pocket ampèremeter described and illustrated below. The core is in the form of a thin sheet of iron cut into a form like half of a new moon, pivoted at its center and connected directly to its pointer, which enables a deflection of more than 180 degrees to be used.

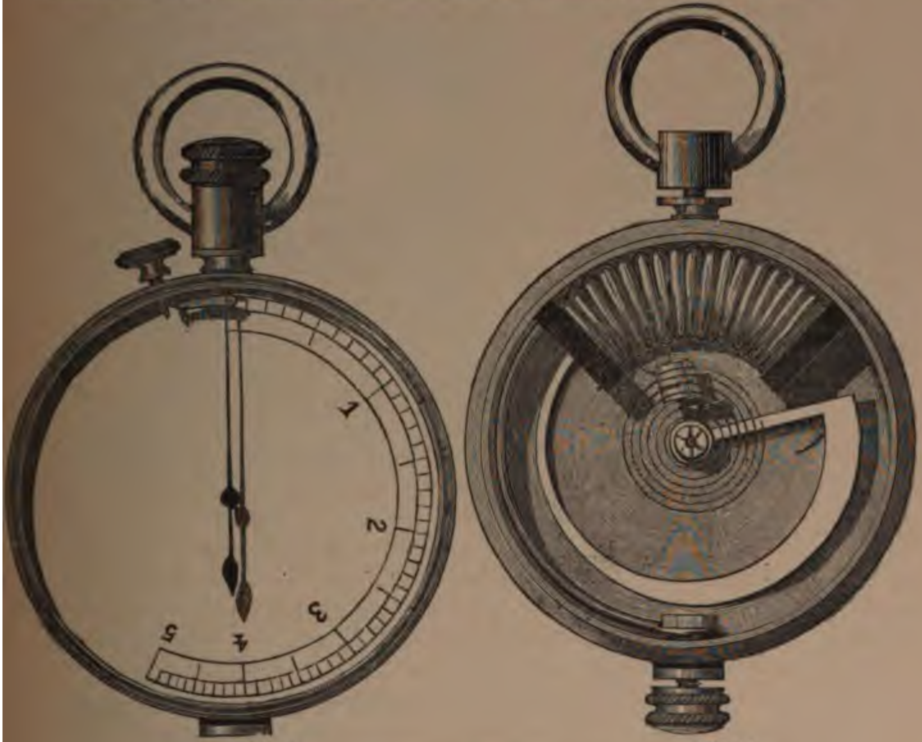


Fig. 54. Fig. 55.

Pocket ampèremeter; Woodhouse & Rawson.

Pocket ampèremeter.—Messrs. Woodhouse & Rawson (French section) exhibited a very convenient form of pocket ampèremeter, having the external appearance of a pocket watch, as seen in the adjoining illustrations, Figs. 54 and 55, which show the face and the internal mechanism respectively. In principle it is the same as the Alioth form just described, the pivoted, crescent-shaped core attached to the pointer being drawn into a curved coil, the counter action being a hair spring. Although probably not very accurate, it is very convenient, and will doubtless meet with favor for certain classes of work. It may, of course, be made equally well as a voltmeter.

Edison.—Edison exhibited a form similar in principle, but used chiefly for very great currents. The core is a round iron rod bent around in the form of a quadrant of a circle, and is pivoted on horizontal pivots at the center of this circle and counterbalanced by a weight. The fixed coil consists of a very coarse spiral of a few turns of thick, bare copper wire, also bent around in the form of a quadrant, so that the curved core moves axially through it. Its construction is certainly very simple, and for strong currents is probably very good.

De Lalande.—Carpentier exhibited also a very simple form devised by Lalande and called an electric hydrometer, consisting of a long vertical solenoid filled in the interior with water, in which sinks an ordinary hydrometer, in the inside of which is a bundle of iron wires; this acts as the movable core which is sucked down against the buoyant action of the water, which replaces the spring used in the similar well-known Kohlrausch instruments. The range is quite large and nearly proportional in the portion most frequently used. The guide for this hydrometer, to prevent its attaching itself to the side of the coil, is under the liquid, whereby the friction is said to be eliminated. It is claimed to be nearly aperiodic (dead beat).

Thomson-Houston form.—In the one usually used by the Thomson-Houston Company (United States section) a small U-shaped piece of soft iron is pivoted near the center of a coil having a square cross section, three sides of which section are embraced by the soft iron piece. The tendency of the coil is to draw this piece closer to it, which it is enabled to do through a great range by the fact that the iron piece is pivoted eccentrically. The counter force is gravity. In the ampèremeters for great currents this coil is a circular piece of cast copper cut at one part and provided there with terminals.

Thomson's form for alternating currents.—A curious form devised by Elihu Thomson, for alternating currents, consists of a solid ring of copper situated in a coil, slightly inclined to it and capable of turning on the common diameter. The currents induced in this ring tend to move the ring into a position perpendicular to the coil. Gravity is the counter force. It is probably only experimental.

Electrometer form.—One of the most important improvements is the application of the electrometer principle to commercial voltmeters. One of these, made by Carpentier, is shown in Figs. 56 and 57. The movable part, shown enlarged in Fig. 57, is made in the form of a light rectangular frame of aluminum, rocking on knife edges in the interior; it rotates so that its long sides move between the eight cylindrical segments, four inside and four outside. The four on a vertical diameter are connected together as well as to the needle and form one pole; the four others form the other pole. When in operation, the needle is repelled by the former and attracted by the latter, the counterforce being gravity. The function of the horseshoe magnets shown is merely to create an intense field through which the aluminum frame moves and by which its motion is dampened so that it is practically aperiodic. It is limited, however, to high voltages, from 500 up. Elliott and Bréguet also exhibited commercial voltmeters on this electrometer principle, resembling more nearly the Thomson electrometer, but with its axis horizontal and a long pointer attached to its "figure 8" needle; these, however, are not aperiodic, which is an important objection, as they oscillate a long time. Those of Elliott are made for as low a voltage as 40, the range of this one being 40 to 160. The advantages of such voltmeters are that their constant is fixed and does not change, that they may be kept in circuit continually, are independent of temperature, and are equally applicable for alternating and for continuous currents.

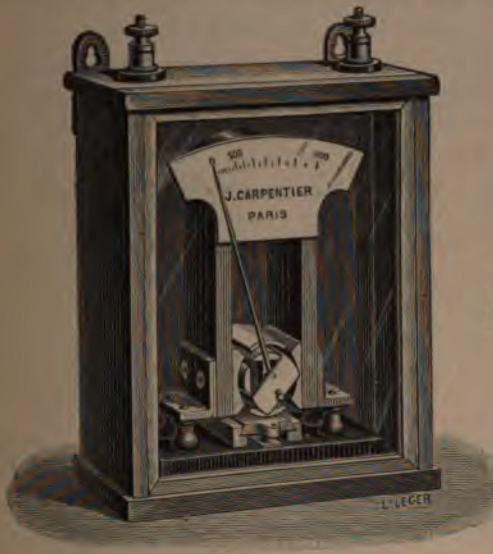


FIG. 56.

Electrometer voltmeter; Carpentier.

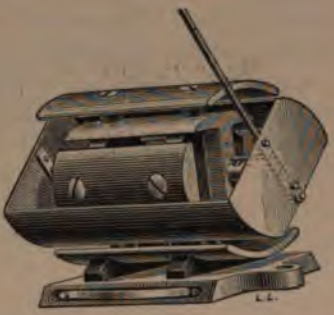


FIG. 57

Thomson standard balances.—The Sir William Thomson standard ampère balances were not exhibited. They are, however, of too great importance to be passed by here without a short description. The object of the instrument is to measure current by devices which remain absolutely constant, which are entirely independent of any surrounding or variable conditions, and which are transportable. It is, in fact, a transportable standard ampèremeter, and belongs to the same class of instruments as the standard ohm, the standard cell, and the absolute electrometer. The principle is that the attraction of the current to itself is measured by being balanced by a weight. The apparatus consists in general of a pair of balances having two flat coils in place of the scale pans. Immediately below each of these there is a fixed coil, axial with the one above. The current passes through all in series in such a direction that two of the coils repel each other and the other two attract, thereby turning the balance. This force is exactly counterbalanced by an adjustable weight sliding on the beam; its position measures this force and therefore the exact current. Their chief commercial use is to serve as a standard in calibrating (by means of a standard resistance) the ampère and volt meters of commerce. They are not intended to replace these. In the newest forms, the range of each instrument is 100 times the smallest unit. The smallest is for 0.01 to 1 ampère and the largest from 25 to 2,500 ampères. Their prices are about $150.

Converter-voltmeter.—Elihu Thomson also exhibited an experimental electrometer voltmeter for low potentials, in which the electrometer was connected to the secondary circuit of a small transformer in which the low potential was converted into one sufficiently high to be measured by the electrometer. This is for alternating currents. For direct currents the transformer was made of a series of condensers like those used in the well-known Planté experiments, which are charged in multiple arc and discharged in series by means of the usual cylindrical commutator, which is rotated rapidly.

Edison voltmeter.—The portable voltmeter used and exhibited by Edison differs essentially from most others. It is in principle a potentiometer, that is, one in which the difference of potential is compared with a standard cell and is measured in terms of that cell, which is contained in the voltmeter as part of it. It consists essentially of a high resistance whose ends are connected to the two points whose difference of potential is to be measured. A standard cell in series with a small galvanometer is connected, as a shunt to a small portion of this resistance, by a sliding contact moved until no current flows through the galvanometer. The required voltage is then a certain multiple of that of the cell. The graduations at the sliding contact are so calibrated as to read directly in volts. The standard cell is a Daniell, made in the form of a small U-tube, having the bend filled with plaster of Paris, and the metals with their respective solutions in the two limbs. The plaster acts as a porous diaphragm and prevents the mixing of the solutions for three or four months. It is air-tight and cheap and is replaced by a new one when used up. They are also made with Clark cells, which appear to be better. The same apparatus is arranged to enable currents or high insulations to be measured with it. Their standards for calibrating all their instruments are the Daniell and the Latimer Clark cells (1.435 legal volts at 15° C.) and the legal ohm.

Edison volt indicator.—The Edison volt indicator differs also in principle from the usual instruments, the principle being that the potential is measured by the change of resistance of the carbon filament of a lamp through which the current passes. It is used in multiple arc distribution merely to indicate the normal potential and a few volts on either side of it.

It belongs to the class of "zero" instruments, and consists, essentially, of a sort of Wheatstone bridge, as shown in the adjoining illustration, Fig. 58, in which an incandescent lamp forms one of the arms of the bridge, the three other arms being ordinary resistance coils. The usual battery is replaced by the leads at which the potential is to be measured. A small galvanometer with an artificial field (so as to be independent of the earth's magnetism) is contained in the apparatus and has a long pointer with a black disk on its end moving over the scale, so that it is readily visible even at a distance.

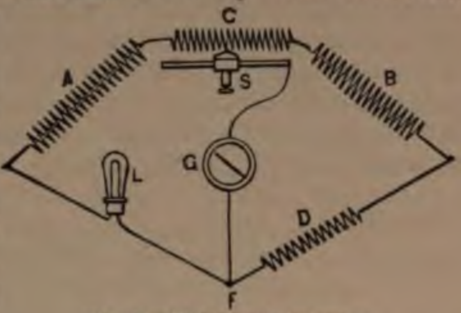


Fig. 58.—Edison's volt indicator.

The system is so arranged that at the normal voltage it is balanced and the galvanometer points to zero, which is marked as the normal potential. If the voltage changes, the current through this lamp will change, which in turn changes its resistance correspondingly, alters the balance of the bridge, and deflects the galvanometer needle. By this means a change of one volt from the normal may be made to deflect the end of the needle half an inch, which can therefore be seen at a comparatively great distance. A small adjustable resistance is added so that the instrument may be adjusted to any desired voltage as a normal. It is to be kept in circuit all the time, one of the resistances being made partly of German silver and partly of copper so proportioned that as they heat up the balance is still maintained. An objection to these instruments is, that the current required by them is great enough to be affected by the resistance of the pressure wires leading back from the points of distribution.

Compound voltmeter.—Messrs. Cuenod Sautter & Co. (Swiss section) exhibited an ingenious voltmeter of some interest, for the following special purpose: In multiple-arc distribution in which mains are led to a central point of distribution it is desired to measure, in the station, the potential at this distant point, thus eliminating the variable loss of potential in the mains. This is usually done by running small potential wires from this point back to the station. These involve no insignificant first cost and cost of maintenance.

The object of this voltmeter is to dispense with these, enabling the desired potential at the far ends of the mains to be read directly from their dynamo ends. It consists of an ordinary voltmeter which has in addition a coarse coil for the main current, the magnetism of which opposes that of the fine wire coil and reduces the deflection by an amount which corresponds to the number of volts lost in those mains. As the magnetism of this coarse coil is proportional to the current the deflection will be reduced correspondingly for any current in the mains. It must, of course, be adjusted for the particular mains for which it is to be used, and it can not be used for any others.

Lippmann ampèremeter.—The ampèremeter of Lippmann, sometimes called the "mercury ampèremeter," exhibited by Bréguet, differs entirely in principle from the ordinary ampèremeters, and has some very good features. Although made in a commercial form, it will hardly replace the ordinary cheaper ampèremeters, but for special cases it has very great advantages. The scale is absolutely proportional, there is no heating error for large currents, and it is aperiodic.

The principle is that a conductor traversed by a current and situated in a magnetic field, normally to the lines of force, will be moved in a direction parallel to itself and perpendicular to the lines of force, and with a force proportional to the product of the current and the intensity of the field. In so far it is similar in principle to the wires on an armature of an ordinary motor. The application of the principle, however, is quite different. A U-shaped tube partially filled with mercury is placed with the bottom part of the bend between the two poles of a powerful horizontal magnet, the field of which is perpendicular to the column of mercury in that part of the tube. The current is then made to pass transversely through this portion of the mercury column—that is, across the column perpendicularly to both the field and the axis of the horizontal column at this point. The repelling force of the current will then cause the mercury to be displaced in the direction of its axis, making it rise in one arm of the tube and fall in the other. This rise or fall will be directly proportional to the current throughout the whole range, which latter is limited only by the heating of the small section of mercury through which the current passes, and which, in practice, is made in the shape of a small parallelopipedal space bounded on two sides by the poles of the magnet and on the other two by the platinum contact plates for the current.

If the strength of this field is known the displacement per ampère can be calculated and the instrument thereby calibrated. This displacement in centimeters is equal to the product of the current in ampères, and the field intensity in c. g. s. units, divided by 133,416 times the thickness in centimeters of that part of the mercury column which is between the magnet poles, measured in the direction of the line of force. It is independent of all other factors and dimensions. With a thickness of one-tenth of a millimeter the greatest sensitiveness produced was 14 centimeters per ampère, the field being 18,678 units. Ordinarily the sensitiveness is from 6 to 12 centimeters per ampère. Others have been made to read up to 1,000 ampères, the permanent magnets being replaced by an electromagnet.

Maximum and minimum voltmeter.—For a maximum and minimum voltmeter, see Deprez galvanometer, under the heading "Galvanometers."

Recording ampère and volt meters.—Richard Frères (French section, gold medal) exhibited a number of their registering ampère and volt meters, which appear to be coming into use quite largely. They are very convenient and quite simple in construction; though not very accurate, they are sufficiently so for many purposes and they will doubtless find great application. A registering ampère-meter for strong currents is shown in the adjoining illustration, Fig. 59.

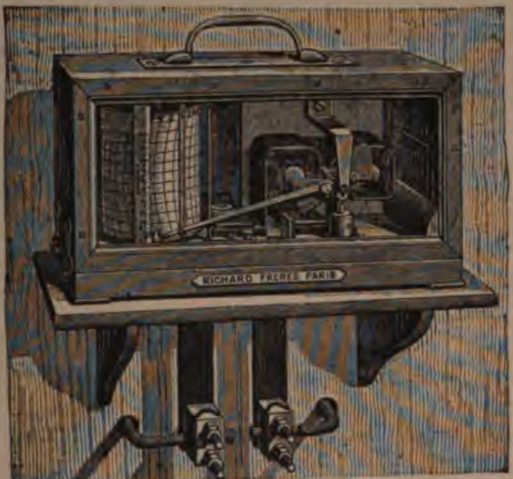


FIG. 59.—Registering ampèremeter.

The galvanometer part is of somewhat crude construction; the two-winged, soft iron armature, shaped somewhat like a butterfly, is pivoted on horizontal pivots and is connected to the pointer; it is so shaped and bent that the deflection is as nearly as possible proportional within the greater part of the range of motion; gravity is the opposing force. The end of the pointer carries the ink in a small receptacle, the point of which acts as a pen. The revolving cylinder contains its clock and turns once in twenty-four hours, the paper for it being printed with the required curved cross hatchings and duly numbered with hours and ampères. It is not necessary that the galvanometer needle be moved with great force, as the fact that the paper moves enables the pointer to overcome the friction at the pen, even though the force is small, only it will not act as promptly. The same recording drum is used by these makers in many of their meteorological recording instruments, which see for a more complete description.

References.—For a voltmeter and a milliampèremeter, see also Deprez d'Arsonval galvanometer under the heading "Galvanometers."

METERS.

The exhibit of meters, though not as full and complete as might be desired, was fairly good, but it can not be said to be even a fair representation of the present state of the art. Most of the meters were French and were characterized by their complicated construction, though some of them are doubtless very good notwithstanding. There were two from the United States and one each from England and Switzerland. With the exception of the Edison meter, they were mostly new, from four to five years back; this branch may, therefore, be said to have developed almost entirely within the past few years. The majority of the exhibits were simply ampère-hour meters, though many are incorrectly called watt meters, their constants being determined for a certain potential which is assumed to remain constant.

Among the French meters the electro-dynamometer is used almost exclusively as the measuring instrument. Among the rest only few novel or interesting points were shown.

Among the difficulties encountered in designing meters are that, for small currents, and often for no current at all, the meters record inaccurately; although the current is small yet the *time* of these small currents in most cases covers the greater part of the day; the product of the two is, therefore, not always insignificant. The writer has noticed one of the best meters exhibited, record current when the circuit was open. Another difficulty is in the clock mechanism when used. A wound-up spring or weight represents so very little energy that it can be used for no work other than to run a pendulum or escapement; if more is required of it, it either needs to be wound up very frequently or else it must be impractically large. It is, therefore, often replaced by an electric-motor device, but this introduces make-and-break contacts, and it is a question which is worse. Although there are at present good meters in the field, yet none of them combine all the desired qualities of simplicity, reliability, accuracy, and cheapness. There is, therefore, much to be looked for in this branch.

In the following description they are divided into watt-hour meters (true), ampère-hour meters, and time meters:

WATT-HOUR METERS.

Cauderay-Frager.—The Compagnie pour la fabrication des compteurs (French section, silver medal) exhibited the Caudray-Frager meter, which is perhaps one of the best known and most frequently used meters in France. It is a watt meter, for alternate as well as continuous currents. In details it appears to be altered frequently, as descriptions and models differ; the generai principle, however, is about the same.

The following description is that of one of the latest forms: The current and potential are measured by an electro-dynamometer, the fine wire, movable coil of German silver for the potential, and the large coil encircling it for the current. The movable coil is suspended by a torsion wire; the true values corresponding to the deflections are recorded on a counter every 100 seconds, as will be described. The usual clock work for determining the time is here replaced by a sort of electric clock, the object of which is to turn a horizontal disk continuously on a vertical axis so that it makes one revolution every hundred seconds. This disk is concentric with the shaft of the counter, but is not connected to the same. It has numerous ratchet teeth around its circumference over which is an arm from the shaft of the counter; this arm has a catch, and when depressed it engages with these teeth and is carried around with the revolving disk; thus, as long as this catch is depressed the shaft of the counter is being turned with the disk, and a corresponding angular movement is recorded on the counter.

The remaining part of the meter has for its object to depress and hold down this catch for a length of time corresponding to the true value of the deflection of the electro-dynamometer at that moment. This is accomplished as follows: A portion of the revolving disk is raised slightly above the rest; this portion may, at present, be assumed to be a sector of the disk, with straight, radial edges; the end of the pointer of the electro-dynamometer which is free to move, is directly above this disk, and its movement when deflected is from the center to the circumference of this disk, the former being its zero position and the latter the position of greatest deflection; when, in the rotation of the disk, the sector passes under the end of the pointer it raises it slightly, and, by a simple spring lever, depresses the catch above mentioned, which locks the disk to the shaft of the counter; the turning of the disk is therefore recorded on the counter as long as that sector is moving under the pointer, which length of time will evidently depend on whether the pointer is near to the small end or to the large end of the sector. As soon as the edge of the sector has passed from beneath the pointer, the latter as well as the lock catch are released, and the moving of the counter is stopped; this takes place once in every revolution of 100 seconds.

It was assumed above that this raised sector had straight radial edges; this would be the case approximately if the deflections of the pointer were proportional to the watts; but as this is not the case, the sector is made with the outline of one edge curved, the nature of the curve being such that the width of the sector at all points is proportional to the true value of the watts for the corresponding position (deflection) of the pointer. This curved edge therefore admits of correcting any error in the proportionality. It therefore admits of placing the electro-dynamometer coil at an angle, for its zero position, in order to increase its sensitiveness; the best angle is said to be half that of the angular range of deflection allowed.

The electric clock mentioned above is an important part of the meter. It consists essentially of a large, heavy escapement wheel and spiral spring, on a vertical shaft, turning alternately to the right and left, and beating seconds. The vertical shaft of this wheel is a flat bar of iron, which turns on its axis between electro-magnets, of which it forms the armatures. Momentary currents in these magnets, when properly timed, will turn this iron armature and thereby oscillate the escapement wheel. The connections for these momentary currents are made by means of a peculiar device, which closes a contact only when needed; that is, when the wheel is not making its full oscillations of half a turn.

The contacts are double, in multiple arc, one being slightly in advance of the other, by which means one of them always remains clean, as there are no sparks produced on the one that opens first; besides this there is a slight friction produced at each closing of the contacts.

They state that during the past year they have never had a case of stoppage due to unclean contacts among 250 meters.

The following figures given by the makers may be of interest: The resistance of the fine-wire bobbin is 2,800 ohms; the temperature error is less than 1 per cent for a range of 20° C. The total maximum error of the whole meter is said to be 3 per cent, while the mean error is about 2 per cent. Below one-tenth of the maximum current of the meter the error becomes larger, it being 35 per cent for a current equal to one one-hundredth of the maximum.

The energy consumed by the meter is given as follows: In the fine coil, 3.5 watts; in the clock, 1 watt; together, equal to one one-thousandth of the total capacity; that in the coarse coil is 5 watts, at the maximum current, making a total of 9.5 watts. The current for the clock is required only every 10 to 12 seconds, for one-quarter of a second, requiring therefore 9 coulombs per hour.

They have had their meters in use for four years, and at present have five hundred in use. The sales during the past two years have amounted to $20,000, and their monthly sales at present amount to $3,000.

Blondlot.—The Blondlot meter exhibited by Henrion (French section), is a true watt meter for alternating or continuous currents. It is simple in both principle and action, and belongs among the better ones of its class.

The current is measured in an electro-dynamometer the series coil of which is quite large so as to produce a uniform field at its center. The deflections of the fine-wire coil are made proportional to the product of the current and the potential, by means of a cam on its axis, over which passes a string with a counterweight. The curved surface of this cam is such that the angular deflection will be proportional to the watts.

The deflected coil is brought back to zero by an electro-magnet, at regular intervals of time determined by a clock which closes the magnet circuit. The angles through which it is moved back are recorded on a counter, as follows: The main axis of the counter is directly opposite to and in line with that of the movable coil of the electro-dynamometer, but normally it is not in contact with it. On the shaft of the counter is an electro-magnet whose armature is on the end of the electro-dynamometer axis, so secured as to allow it to approach toward the magnet; when this magnet is excited the two shafts are thereby coupled together. The current for this magnet is closed during the interval when the other magnet moves the electro-dynamometer coil back to zero; these angles are thereby all recorded and summed up on the counter.

There were a number of others, such as the Clerc, Gravier, Mildé, and Chambaud, which were somewhat similar in principle to these; some with self-winding clocks; some in which zero readings only were used. No good description of these could be obtained.

Brille.—The Brille meter, exhibited in the central station of the French Edison Company, is a true watt meter for continuous currents, and, it is claimed, may be arranged for alternating currents also. It is simple in principle but somewhat complicated in construction, though its complication is not of such a nature as to be likely to make it unreliable.

In its principle it belongs among the better class of watt-hour meters exhibited. Owing to its complicated construction it can be described here in principle only. The current and potential are measured by an electro-dynamometer, the coarse fixed coil of which is for the main current, and the fine wire movable coil for the potential, the counter force for the latter being obtained from a special spring; the deflecting force is proportional to their product. Every 36 seconds (one-hundredth of an hour) the deflected coil is moved back to zero by turning the torsion head or free end of the counter-spring, the angle through which it is turned being recorded on a suitable counter with dials.

The rest of the apparatus consists of a clockwork which starts the mechanism every 36 seconds, and a motor which moves the coil back to zero and which rewinds the clockwork after every reading; an additional device starts the pendulum of the clock should it have come to rest by a stoppage of the current. The motor consists simply of an electro-magnet having three iron armatures, one for moving the coil back to zero, one for rewinding the clockwork, and one for operating a contact. This magnet is put in circuit every 36 seconds by the clockwork and is cut out when the whole cycle of operations is finished. The various operations are determined by several sets of contacts which make or break the fine-wire current.

This is probably the weak point of this meter, as a current of such high voltage and with such self-induction coils in circuit can not but give a spark, which in time must affect the contacts and require them to be cleaned. In order to properly measure and integrate the angles through which the spring of the coil is turned to bring the coil back to zero, the lever arm which turns it must move with a constant velocity; this is accomplished by a fan escapement and an ingenious friction governor.

By properly proportioning the parts, the constant of the instrument is readily made unity so that the reading is direct in watt hours. It will be noticed that in principle it is a true watt meter, and that such factors as friction and temperature are practically eliminated. It is suggested also to run the clocks of all meters in a plant by a special circuit, in which case the apparatus is simplified and it may then be used for alternating currents also. A very good illustrated description will be found in La Lumière Électrique, August 18, 1888.

Aron.—The Aron meter for continuous currents, exhibited by Danzer (French section), consists essentially of two 40-day pendulum clocks with independent works and pendulums adjusted to run absolutely alike. The current retards or accelerates the motion of one pendulum while the other moves unobstructed; this causes a difference in the running of the two clocks, which difference is measured and recorded by a simple five-dial counter, the readings of which are said to be proportional to the quantities to be measured. The counter is operated by a planet movement, and registers only the difference in the running of the two clocks.

The electrical part is different, depending on whether it is an ampère-hour meter or a watt-hour meter. In the former, one of the pendulums has at the bottom a steel magnet, which, by the oscillation of the pendulum, moves to and fro over a fixed solenoid through which the main current passes; the relative action is an attraction, which accelerates the oscillations of that pendulum, causing a corresponding difference between it and the other. It can evidently be used only for continuous currents.

For the watt meter, the bottom of the pendulum carries a fine-wire solenoid, connected as a shunt across the mains; this moves axially to and fro through the interior of a large fixed solenoid through which the main current passes. The mutual action between the two coils is proportional to the watts; the effect on the pendulum will therefore depend on both the volts and the ampères, and is said to be proportional to their product, the watts.

The readings of the counters are said to be proportional to the ampère hours or watt hours, but they must be multiplied by an empirically determined constant to reduce them to ampère or watt hours. They appear simple and reliable, but it is a question whether the readings are truly proportional for wide ranges of current.

Boiron and Cozette.—In this meter (French section) a small shunt-wound dynamo drives a fan escapement. A set of dials integrates and indicates the number of revolutions. It is called a watt meter. Apparently the main current passes through the armature, and the potential current through the field. It is probably only experimental.

For other watt-hour meters, so called, see under ampère-hour meters below.

AMPÈRE-HOUR METERS.

Any ampère-hour meter may be, and often is, used as a watt-hour meter by assuming that the potential remains constant, in which case the meter may, and correctly too, be made to read in watt hours or energy, in place of ampère hours or current quantity. In a technical classification like the present, however, they belong strictly to ampère-hour meters, and are therefore classed under this heading.

Hookham.—The Hookham meter (English) was exhibited by the Compagnie Électrique (French section). The principle is exceedingly simple and is essentially as follows: The current to be measured drives a small electric motor which moves a solid disk of copper through a magnetic field which therefore acts as a brake or counterforce. The stronger the current, the faster the motor will tend to move, but at the same time, the greater will be the counterforce of the brake. The conditions are so chosen that the resulting speed will be proportional to the current. The revolutions of the shaft are transferred to a simple counter with dials. It is therefore an ampère-hour meter for continuous currents only, but it is made to read directly in board of trade units (kilowatt hours) by assuming a constant difference of potential of 110 volts for instance.

The construction is quite simple and ingenious. The armature is in the form of a thin flat disk of solid copper, on one side of which are secured the radial armature windings, interconnected at their outer and inner ends so as to form a simple armature winding. The whole forms a thin flat disk. The current passes through these windings by means of two commutators or collectors revolving in two mercury troughs. The solid copper disk revolving with it, generates in itself Foucault currents which oppose the revolutions, thereby acting as a counterforce. If the field is constant, this opposing force varies as the velocity, while the force to turn the motor varies as the square of the velocity. The resulting velocity will therefore vary as the current, and may therefore be used as a measure of the ampère hours.

The field magnet is a permanent magnet made of bars of steel and tungsten inclosed in a brass tube and secured to two pole pieces, between which the armature revolves. The field, or space between these pole pieces, through which the disk armature moves, is very short or thin in order to keep the field as strong and as constant as possible, as the principle of this meter depends on the constancy and strength of this field. These magnets are made with great care, and they are said to have been found to remain constant in a large number of meters after fifteen months of use. It is said that they are made constant by magnetizing them and then reducing their magnetism by about 10 per cent, so that their tendency will be to strengthen rather than to weaken. The conditions are so chosen that the effect of other retarding forces may be neglected. The armature revolves quite slowly. There is no oiling necessary, as the shaft rolls on disk wheels, which themselves roll on others, which again roll on a third set.

If the proportionality of the current to the revolution, and if the constancy of the field are what is claimed, it appears to be a very good and simple meter, for the purpose for which it is intended.

Jacquemier.—The Jacquemier meter exhibited (French section, silver medal), is an ampère-hour meter for continuous currents. It is too complicated to be described here, except in principle. It contains many levers, springs, gears, etc., of a complicated and delicate nature, which is one of its weak points.

The current is measured in an electro-dynamometer, the fine wire movable coil of which is an electro-magnet and is in shunt circuit to the mains; its magnetism is assumed to be constant, and the apparatus is therefore a galvanometer. This coil is deflected against the action of a double spring, a light one for small displacements and a strong spring for the larger ones.

There are two clockworks running fifteen days, one for determining the intervals of time of five minutes at which the measurements are made, and the other to do the work of recording the deflections. Every five minutes the former starts the latter, which operates a delicately-balanced searching lever, which moves toward the deflected pointer of the galvanometer; the moment the lever touches it, it is thrown out of balance and the second clockwork is thereby stopped at its fan escapement; the path which it has traveled before it touches the pointer is registered on the counter by the clockwork. After this the clockwork brings the parts back to their normal position.

The deflections are not proportional; this is corrected in the registering apparatus by a train of gears, two of which are not circular, but have an irregular periphery. There are no contacts made or broken, which is a favorable feature.

Aron.—See under the watt-hour meters.

Edison.—The Edison meter is too well-known to need description here. It is essentially a zinc voltameter and measures coulombs, or ampère hours and is for direct currents only. For a well-illustrated paper on this subject see that of W. J. Jenks, American Institute of Electrical Engineers, December 18, 1888.

Alioth.—The Alioth meter (Swiss section), measures ampère hours. A core moves vertically in a solenoid. A 40-day clock drives the counter through a simple intermediate mechanism which depends on the position of the core in the solenoid. The farther the core is drawn into the solenoid the faster the counter is driven by the clockwork. The inequality in the proportion of the current to the movement of the core is corrected by a corresponding curved piece in this intermediate mechanism.

Heinrich & Mulberger.—An electric clock drives a train of gears; a Deprez galvanometer, presumably for the main current, operates on a pulley of this gearing by means of a string and weight which act as a variable brake. Presumably the difference between the normal speed and the retarded speed of this pulley integrates the ampère hours, which are indicated on dials. It is probably only experimental.

Thomson.—The meter exhibited among the apparatus of Prof. Thomson (United States section) is for alternating currents only. The main current passes through a transformer in the meter; the secondary current of this transformer is the one measured in the meter.

The meter consists of a horizontal glass tube with two vertical bulbs at its ends like a so-called "pulse glass." This rocks about a center like a scale beam. The tube and bulbs are partially filled with a volatile liquid; above the liquid in each bulb is a small coil through which the current passes and which is thereby heated. First, one of these is heated by the current, which then causes the liquid to move into the other bulb; this causes the beam to tilt over to the other side, which then switches the current by means of mercury contacts to the other coil, which in turn forces the liquid back and causes the beam to tilt again. This rocking of the lever is registered on suitable dials, which read in watt hours.

In the transformer there is an additional coil of fine wire, the terminals of which are across the mains, the current in which is therefore proportional to the potential of the mains. The function of this is presumably either to make the meter measure the volts also, and therefore the watts, or else, and more probably, it is to introduce a constant force to overcome the friction and similar losses in the apparatus, the potential being assumed to be constant.

Borel.—The Borel meter (Swiss section, bronze medal) is an ampère hour meter for alternating currents only. In the latest form it consists essentially of two flat bobbins in multiple arc, whose core space has a cross section of a flat, oblong rectangle. These are mounted, side by side, so as to have a common axis. In the flat rectangular core space is a thin flat disk of iron capable of revolving about a vertical axis and acting as an iron core common to the two coils. There are also two straight iron bars running through the two coils parallel to the axis, and almost tangential to this disk, but not touching it; their alternate ends project and are bent over. These iron bars and the iron disk are both magnetized by the alternating current, but owing to their shape, position, the Foucault currents produced in them, and hysteresis, the magnetic phases will differ in such a way as to produce a continuous repulsion and consequent rotation of the disc in one direction; this rotation is used as the measure of the current and is transmitted to a counter with dials. On the same axis are secured a set of four fans which act as the opposing force. Their resistance in the air is proportional to the square of the velocity; the rotating action is said to be approximately proportional to the square of the current. On account of the want of true proportionality, two of the four fans are hinged at their top edge so as to offer less resistance as the speed increases. In this way a proportionality is said to be secured between certain limits.

From published results it appears that it is not very reliable and accurate. It is said to be used at the Ferranti Station. Two hundred are said to have been in use in Nancy for a year. A good and well illustrated description of an earlier form will be found in La Lumière Électrique, July 14, 1888, p. 53.

TIME METERS.

Aubert.—The Aubert meter (Swiss section, honorable mention) is simply a time meter, to measure and integrate the number of hours during which the current has been turned on. It is of use merely for constant currents, but for such it appears to be good, simple, and cheap. It consists of a clockwork running 200 hours. It indicates on four dials the minutes, hours, tens and hundreds of hours. It is a simple clockwork, the escapement of which is released by a magnet when the current is started. There are said to be over two thousand in use. It sells for only $7. It is equally good for alternating as for continuous currents.

MISCELLANEOUS MEASURING INSTRUMENTS AND APPARATUS.

Standard cell.—In the educational department (United States section) was shown a standard Daniell cell devised by Carl Hering, the object of which is, to have a simple form of cell which is always ready without being refilled every time it is to be used, and in which the liquids, which must necessarily mix at their junction, are drained off at their junction faster than they can mix, thus preserving the two liquids absolutely pure. The arrangement is shown in the adjoining illustration, Fig. 60.

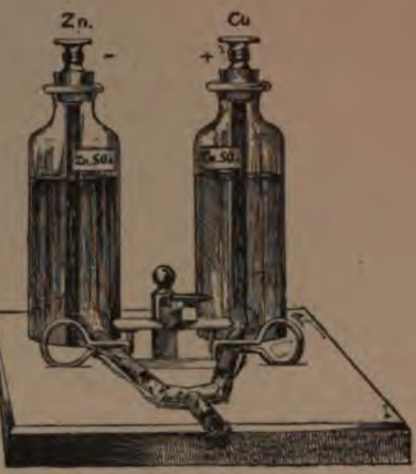


FIG. 60.—Hering's standard cell.

It consists of two bottles containing the two liquids and their respective electrodes. They are joined together at the bottom by means of a three-way tube having stopcocks and containing some filtering paper or other porous material to prevent too rapid flow of the liquids. The third tube communicates with the air from the junction and through this the mixed liquid at the junction is drained off drop by drop faster than it can mix. When not in use the cocks are turned to prevent waste of the liquids.

The electromotive force of such a cell, with solutions of pure copper and zinc sulphates, both having a specific gravity of 1.20 at about 60° F., using pure electroplated copper and pure amalgamated zinc, is 1.105 true volts.

Pyrometer.—Carpentier exhibited an electric pyrometer devised by M. le Chatelier, which appears to be a very satisfactory instrument, and which is said to be used largely; it is very conveniently arranged, considering its accuracy and range.

It consists of a thermo-couple connected directly to a galvanometer. The electromotive force of this couple increases with the temperature; the current through the galvanometer is, therefore, a direct measure of the temperature. The thermo-couple is made of platinum and platinum-iridium alloy of 10 per cent, which gives good results up to 1,200° C. or 2,200° F.; it is at the end of a long rod by which it is introduced into the furnace. The galvanometer is of the Deprez-d'Arsonval form (which see under galvanometers) arranged in a very practical form with lamp and scale, so as to be portable; it is in the form of two flat boxes, one containing the galvanometer and the other the lamp and scale; to use it, these two boxes are hung on the side of a wall one meter apart. The apparatus gives a deflection of 10 centimeters (4 inches), for 1,000° C. (1832° F.)

For an illustrated description see La Lumière Électrique, June 30, 1888, p. 604, which article contains also descriptions and references to descriptions of other pyrometers.

Photometer.—Messrs. Patterson & Cooper (British section) exhibited a photometer devised by Thompson (S. P.) and Starling. It differs from the ordinary photometer in the following points: That the paper with the grease spot is replaced by two disks of plain white paper at an angle to each other, so that both can be seen at the same time, the one being illuminated by the candles and the other by the light to be measured; the screens and the lamp are fixed and the candles moved; two candles are used to eliminate partially the errors in the candles.

It is arranged in a very convenient form so as to facilitate readings, the scale being so spaced that the readings are direct, even for very high candle powers; the only reductions are multiples of 10. The correction for a mirror which is used for bright lights is made by the constructor in fixing the space between the lamp and screen. The whole arrangement of the photometer is very convenient, but it is doubtful whether its accuracy is as great as in the ordinary form, as a number of slight errors appear to be introduced by this construction.

Magnetic and fluid bridges.—Edison exhibited his magnetic bridge, the object of which is to enable one to measure the magnetic properties of samples of iron to be used for dynamos.

It is based on the principle of the Wheatstone bridge, in which the electric current is replaced by the magnetic flux. The battery is replaced by a large magnet, and the galvanometer is replaced by a magnetic needle, which is situated between the two points where magnetic balance is to be reached. The three arms of the bridge are of fixed pieces of iron while the fourth is made of the sample to be tested. No means are given for bringing the needle back to zero, that is, for producing balance. The samples of iron are so short that the magnetic resistance at the two contacts forms perhaps the greater part of the whole resistance to be measured. While it is ingenious in principle it is probably of little use in practice for the reasons given.

Edison also exhibited a fluid bridge, the object of which was to measure the resistance of liquids, the principle of which was also that of the Wheatstone bridge. Both of these are no longer new.

Tasimeter, etc.—Edison exhibited a number of instruments for different purposes which depend for their action on the change of resistance of a carbon button under variable pressure, this variable pressure being produced by different substances. In the tasimeter, for instance, it was produced by a piece of hard rubber, and was used as a means of measuring very small differences of temperature, as, for instance, that of the heat from a star. The expansion of the hard rubber compresses the button. In a hygrometer this was made of gelatine which expands by absorption of moisture.

Thomson's apparatus.—By far the most interesting and novel apparatus for scientific researches and demonstrations was the alternating current apparatus of Prof. Elihu Thomson (United States section, grand prize). It attracted very great interest among scientists as among technical engineers, and owing to the striking phénomena it was interesting even to the general public. The apparatus and the phenomena, though new, have been so thoroughly described in the American techical journals, that it is needless to repeat a description here.

The main phenomenon, which Thomson no doubt was the first to notice, is briefly as follows: If a closed metallic circuit, such as a ring, sheet, or other mass of copper, be brought near a coil in which an alternating current passes it will be repelled from the same.

The explanation is, briefly, that a current is induced in this mass of copper which at one instant is attracted and at another instant is repelled from the original or primary current. These attractions and repulsions would be equal and would therefore balance if the secondary current flowed without retardation, but owing to the fact that the secondary current is retarded in its flow by self induction, the repelling force becomes greater and the attracting force less, and there is therefore an excess of the former, or in technical terms, the waves of the two currents differ in time by a fraction of a wave length, thereby causing a preponderance of the repelling force over the attracting force.

This phenomenon was shown by several striking experiments. A solid ring of copper held over the end of an alternating-current magnet was kept floating in the air above the magnet by this force. When forced down over the magnet and then released it was projected up into the air. A hollow sphere of copper was floated in a tank of water placed over this magnet, and when a sheet of copper was placed between the magnet and the ball so as to cover half of the end of the magnet, the ball would rotate rapidly and with considerable force; the copper sheet acts as a screen to cut off the action from one half of this sphere, the other half being continually repelled, causes the sphere to revolve.

A number of applications of this principle of repulsion were shown, one of which was an alternating current motor, which see under "Dynamos."

Another apparatus of interest exhibited by Thomson was an instrument for studying the waves of alternating currents. It consists essentially of an iron diaphragm, opposite to an electromagnet, through which the current to be studied passes. Its motion is communicated to a small mirror by a lever, which also enlarges the motion. A beam of light is reflected from this mirror on to a ground-glass plate, on which, therefore, a line would be produced, when the mirror oscillates, by the action of the alternating current.

This line becomes a "figure-8" shaped diagram when the whole apparatus, except the glass plate, is moved rapidly to and fro by hand.

In another form the mirror is under the action of two magnets, giving to it a motion in two directions perpendicular to each other, by which the relative action of the waves of two currents, primary and secondary, for instance, can be studied.

Influence machines.—Influence or induction machines for generating electricity of very high tension and small quantity, often called static electricity, were exhibited by numerous makers. They were all of the "induction" type, in which the electricity is generated by the static induction of one electrified body on another, as distinguished from the original Franklin friction machines, which exist now only as historical apparatus. Most of them were of the well known Wimshurst type and a few of the less frequently used Holtz and Carre type. The former seem to be replacing the others rapidly, as they have numerous advantages in simplicity and in their action, being, it is said, affected less by humidity, and will not lose their charge, like the Holtz type.

The finest exhibit of a Wimshurst machine was that of Ducretet (French section), which had twelve glass plates, 26 inches in diameter, giving sparks 16½ inches long, at the rate of one or two per second. It is said to be the largest one ever built. The finer ones are always inclosed in glass cases. In some cases the glass plates are replaced by hard rubber, which is much more durable, as the glass is likely to crack and burst. They are used chiefly for demonstration purposes, but they have lately come into use largely for testing cables during their manufacture. They are also used largely for medical purposes.

Geissler & Crook's tubes.—The principal exhibits of Geissler & Crook's tubes were those of V. H. Seguy et Fils (French section, bronze medal), and M. Anselme (French section, honorable mention), both of which were very creditable exhibits.

Speed register.—Bréguet exhibited a speed register of Duveau. Its description does not belong here, as it is not electrical, with the exception of one feature of particular interest, which is applicable also to other apparatus, notably to chronographs. This is a small electric motor, whose speed is absolutely constant, no matter how much the current which drives it varies. It consists of a small four-pole frame and a Siemens H armature. The current driving it is alternated by means of contacts on a tuning fork, which is kept vibrating by the usual electric apparatus. The speed of the motor must synchronize absolutely with the alternations of the current, as it will run only under those conditions. As these alternations are produced by the tuning fork, the speed of the motor is as constant as the vibrations of the tuning fork, and is entirely independent of the strength of the current.

Binding posts.—For a description and illustration of some binding posts see under "Accessories," p. 87.

VI.—THERMO-GENERATORS.

General.—In apparatus for obtaining electricity directly from heat, or obtaining power from heat by means of magnetism, there was almost nothing of interest, although some new developments have been made within the last few years, none of which, however, have advanced farther than the laboratory.

The only novelty exhibited was the pyromagnetic motor of Edison. The thermopile seems to be the only converter of this class which has developed to a commercial apparatus, and it appears that this, like the steam engine, has reached a practical limit of development which, at best, leaves it a very inefficient converter of energy. This field, which ranks among the most important in science, is at the same time one of the most undeveloped.

Besides the Edison motor mentioned, a few slightly improved thermopiles constituted all that there was exhibited in this important field.

Chaudron.—J. B. Chaudron (French section, bronze medal) exhibited a thermopile, the chief claims for which are its details of construction. It does not, however, differ greatly from the usual Clamond forms. The elements are tinned iron for the positive pole electrode, and Marcus metal, consisting of two parts antimony and one part zinc, as negative pole electrode. They are arranged in circular layers as usual, with ten couples per layer. The interior cylindrical space is lined with a tube of refractory material; the hot gases from a Bunsen burner pass through a concentric tube perforated with numerous holes which distribute the heat more evenly.

The temperatures are said to be 350° C. (662° F.) on the inside and 80° C. (176°F.) on the outside, making a difference of 270° C. (486° F). The electromotive force of each element as measured by Hospitalier is 0.061 volt; for a battery of 50 elements it was 2.9 volts, internal resistance 0.38 ohms, current on short circuit 7.4 ampères, maximum available energy one-fourth (2.9 by 7.4) = 5.4 watts; consumption of gas 200 liters (7.06 cubic feet) per hour. This corresponds to 1,060 cubic feet of gas per effective horse-power hour, which at the rate of $1.80 per 1,000 cubic feet, is $1.90 per horse-power hour.

Reynier and Fontaine give the cost of a horse-power hour from batteries, from 40 cents to $1.60, so that the cost of power from this thermopile is not much greater than that from some poor batteries. In its application, however, the great convenience of a thermopile as compared to a battery, is of great importance. Besides this the waste heat from the thermopile may be considered as a by-product which can be used for heating in winter and ventilating in summer. They are said to be used chiefly for galvanoplastics, and for laboratories; also in a few cases to charge accumulators.

Clamond-Carpentier.—Carpentier (French section) exhibited a form of Clamond thermopile, which is quite similar in most of its details to the one described above. The metals used are iron or nickel, and an antimony-zinc alloy of equal parts. It is arranged in a convenient form with a burner and refractory lining similar to the one described above. For illustrations of this pile, as well as a description of several others, see La Lumière Électrique, April 14, 1888.

Chalk battery.—In the Edison exhibit was shown a "chalk battery" in which two palladium-faced springs slide on a cylinder of chalk and on its brass mandrel respectively; on revolving the cylinder by hand a current is said to be produced. In the appended description it says "it has as yet been undetermined as to what this is due to." It has been classed here, as its action may possibly be thermal.

Pyromagnetic motor.—In the Edison exhibit was shown a small pyromagnetic motor, which was the only apparatus exhibited for obtaining mechanical energy from heat which was a new departure from the well-known methods. Though not yet a commercial success, it at least represents one of the very few new directions of development in this most important and poorly-developed field.

It is based on the well-known fact that iron loses its magnetic qualities on being heated. A cylindrical iron armature is supported on a shaft to allow it to rotate, as in a dynamo, between the poles of a magnet. Hot gases are passed through this armature so as to heat that portion through which the lines of force pass; these lines are thereby deflected into the adjoining colder portions which are thereby attracted to the magnets and in turn become heated, and so on, giving the armature a continuous, rotary motion. Although the motion is necessarily slow, the force developed may be quite great.

For a history of what has been done in this field prior to Edison's application of this principle, see Franklin Institute Journal, October, 1887.

Pyromagnetic generator.—A similar principle was applied by Edison to a generator of electricity, in which the lines of force in being deflected, passed transversely over a series of wires in which, therefore, a current is produced. The difficulty, however, which was the prime cause of its failure as a commercial generator, was that in order to develop a moderately high electromotive force the rapidity of the heating and cooling was too great to be practicable. The generator was not exhibited.

VII.—WIRES, CABLES, AND CONDUITS.

General.—The exhibits of bare wire were confined almost entirely to the French section, and were in general very creditable, showing fineness of work and results of considerable and apparently successful research to obtain a mechanically strong wire of high conductivity for line wire.

High insulation, water-proof wires were equally well exhibited by France and the United States; in the former the insulation used was almost entirely of soft rubber and gutta-percha, while in the latter it was principally paraffin and rubber compounds.

The cable exhibits were confined to a few large, well-known companies from France and England. The cable industry in France has developed almost entirely during the last ten or fifteen years, before which time their cables were made almost entirely in England.

There were a few insulated wire exhibits from Russia, Japan, and elsewhere, but without particular interest.

Historical.—Among the historical exhibits was a sample of an underground wire laid between Baltimore and Washington in 1844. It consisted simply of a copper wire, about No. 18 B. & S. gauge, covered with an insulating compound and inclosed in a lead tube. It was exhibited by the Western Electric Company.

BARE WIRES.

The exhibit of bare wires of the firm of J. O. Mouchel (French section, gold medal) was undoubtedly the finest of its kind and was particularly interesting on account of the fineness and regularity of their goods, as also on account of the very elaborate researches made by them with different alloys, to obtain great tensile strength combined with good conductivity for lines wires, and to obtain great resistance with small temperature coefficient for resistance coils.

These are probably the oldest wire manufacturers in France, dating as far back as 1709. They employ at present 200 hands (of whom 120 have been there more than ten years) and 450 horse power. Their specialty is fine, delicate work, purity of alloys, length of pieces, and regularity of diameter.

Impurities in copper.—The following table gives the results of their elaborate experiments made in 1884 to study the effects of impurities of small quantities of foreign metals alloyed with copper:

Wires 0.50 millimeter diameter, annealed. Alloys of pure copper with 1 part of the following metals (pure) in 1,000.	Resistance per kilometer in legal ohms at 0° C.	Conductivity.	Elongation. Per cent.	Ultimate tensile strength in kilograms per square millimeter.
Lead	78.21	104.04	36.20	19.09
Molybdenum	78.78	103.28	33.50	21.90
Cobalt	79.17	102.77	38.15	20.62
Silver	79.30	102.60	4.25	29.02
Sulphur	79.31	102.59	37.55	21.51
Gold	79.35	102.54	32.45	20.62
Selenium	79.43	102.44	30.42	27.23
Thallium	79.44	102.42	36.10	21.26
Zinc	79.59	102.22	35.32	27.06

Wires 0.50 millimeter diameter, annealed. Alloys of pure copper with 1 part of the following metals (pure) in 1,000.	Resistance per kilometer in legal ohms at 0° C.	Conductivity.	Elongation. Per cent.	Ultimate tensile strength in kilograms per square millimeter.
Antimony	81.30	100.08	30.00	22.91
Tellurium	81.50	99.84	1.82	41.35
Platinum	81.98	99.25	38.80	20.37
Nickel	82.72	98.37	39.00	20.88
Tungsten	84.08	96.77	36.85	21.51
Tin	84.49	96.31	3.65	32.42
Chromium	85.64	95.01	33.55	22.92
Magnesium	86.29	94.29	3.75	36.54
Aluminium	89.86	90.55	35.20	22.15
Manganese	90.09	90.31	33.75	27.57
Iron	97.65	88.32	32.65	22.05
Arsenic	105.17	77.36	39.10	21.77
Silicon	120.44	67.55	20.65	18.33
Phosphorus	149.84	54.30	31.25	23.42
Bismuth	Unmanageable.			
Cadmium				
Potassium				
Sodium				

Alloys of copper—The different effects of different proportions are seen in the two following striking examples: one tenth of 1 per cent of phosphorus reduces the conductivity of copper to 54.30 per cent, while 5¼ per cent reduces it only to 10.079 per cent. With arsenic one tenth of 1 per cent reduces copper to 77.96 per cent, while 5 per cent reduces it to 5.72 per cent.

Pure copper.—They exhibited also a pure copper wire, the conductivity of which is 104.69 per cent deduced from measurements which were controlled at the Vienna Exposition and certified to by Messrs. Blavier, Stefan, and Discher. This very high conductivity of copper, which is doubtless correct, simply shows that the generally accepted value for pure copper is too low. Next to this exhibit of remarkably high conductivity there was shown, by way of contrast, a similar wire of 0.50 millimeters of remarkably high resistance, made of an alloy of copper and arsenic, having a resistance of 2,335.50 ohms per kilometer, which is equivalent to a conductivity of 3.48 per cent, or about double the resistance of German silver.

Commercial copper.—Their regular copper telegraph wire, annealed, has a conductivity of 102.5 per cent, an elongation of 35 to 38 per cent, and a breaking strain of 20 to 25 kilograms per square millimeter (28,000 to 35,000 pounds per square inch), depending on the degree of annealing. The coefficient of temperature is 0.40 per cent per degree centigrade.

Bronzes.—Their two principal bronzes have 98.5 per cent with 45 kilograms (64,000 pounds per square inch), and 34.6 per cent with 75 to 90 kilograms (107,000 to 128,000 pounds per square inch) as conductivity and breaking strain respectively. These can be wound around a wire of their own diameter without showing any breaks. The former will stand twenty bendings in a vise, and the latter thirty to thirty-five.

Magnesium bronze.—Their experiments with magnesium have given very interesting results, showing great strength combined with good conductivity. The following figures show some of the results:

Conductivity.	Breaking strain.
Per cent.	*Kilograms per square millimeter.*
95.16	51.60
81.60	61.09
63.80	75.17
58.01	81.37
51.43	95.49
50.61	76.47

They find it impracticable to go below 50 per cent conductivity, or above 70 kilograms breaking strain. For exceptionally great spans of line wire they have arrived at 100 to 110 kilograms with a conductivity of 21 per cent. These figures are nearly the same as those of the silicium bronze wire exhibited by Weiller, described below.

Resistance wire.—Their German silver resistance wire has a conductivity of 7.35 to 4.40 per cent. They find that while all known alloys increase in conductivity on being annealed, the German silver will decrease when the proportion of nickel is greater than 10 per cent.

Their new high resistance arsenic alloy, containing 10 per cent of arsenic, has a conductivity of only 3½ per cent and a temperature coefficient of only 0.0258 per cent per degree centigrade (that of German silver being 0.0393 per cent). This alloy is very difficult to work, but in spite of this they exhibited it drawn to the remarkably small diameter of seventeen thousandths of a millimeter, or 0.00067 inch, or about one-tenth as fine as No. 34 American gauge. The resistance of this wire is 2,052 ohms per meter.

Another curiosity which they have made is a coil of telegraph wire in a single piece (without any joints) weighing 660 pounds. This was before electric welding came into use.

Silicium bronze.—Lazare, Weiller & Co. (French section, gold medal) had a fine exhibit of bare wire, chiefly of their patent Silicium bronze, which appears to be their specialty. They claim as advantages for this line wire, over the usual iron or steel wire, that for the same conductivity the weight per mile is several times as small; that, therefore, it is much easier to run; that it diminishes the dimensions and number of poles and insulators; and that, owing to its increased strength, there is less danger of rupture from wind and snow; also that it is absolutely inoxydizable.

Properties.—The following figures taken from their tables show the most important properties. For long telegraph lines a silicium-bronze telegraph wire of 2 millimeters diameter (0.079 inch, or about No. 12 B. & S. gauge) weighing 28 kilograms per kilometer (100 pounds per mile) has the same resistance as, and can replace, the usual galvanized iron wire 5 millimeters in diameter (0.197 inch, or about No. 4 B. & S. gauge) weighing 155 kilograms per kilometer (550 pounds per mile) and having a resistance of 5.40 ohms per kilometer (8.7 ohms per mile). For telephone lines, a silicium-bronze wire of 1.1 millimeters diameter (0.043 inch, or about No. 17 B. & S.) weighing 8.45 kilograms per kilometer (300 pounds per mile) has the same resistance and can replace a steel wire of 2 millimeters diameter (0.079 inch, or about No. 12 B. & S. gauge) weighing 25 kilograms per kilometer (89 pounds per mile) and having a resistance of 40 ohms per kilometer (64 pounds per mile).

The conductivity and tensile strength may be varied at pleasure, for different purposes; as one quality increases, the other diminishes. The following figures, showing the properties, are taken from their tables, and are here reduced to our units:

Size of silicium-bronze wire 1.5 millimeters, or 0.059 inch, or No. 15 B. and S. gauge.

	Weight in kilograms per kilometer.	Weight in pounds per mile.	Tensile strength in kilograms per square millimeter.	Tensile strength in pounds per square inch.	Resistance in ohms per kilometer.	Resistance in ohms per mile.	Conductivity in per cent as compared with copper (having 20.57 ohms per kilometer per 1 millimeter diameter).
For long distance telegraph lines.	15.75	56	45	64,000	9.45	15.2	97
For long span telegraph lines ...	15.75	56	56	79,600	11.42	18.4	80
For telephone lines...............	15.75	56	75	106,600	28.8	46.4	32
For telephone line, new type...	15.75	56	80	113.800	21.77	35.0	42
For long span telephone lines ...	15.75	56	112.5	160,000	43.58	70.0	20

Bi-metallic.—Charles Martin & Co. (French section, bronze medal) exhibited a line wire called "bi-metallic," consisting of a core of steel, and a thick solid layer of copper around it and united to it. The proportions of copper and steel are about half and half. It is made not only for telegraph and telephone lines but also for the transmission of power and light, as well as for electric bell circuits. Pure copper wire would be best for lines were it not for the high price, and the fact that, as it is so soft, it is apt to tear when in long spans, or to elongate by its own weight, thereby diminishing its cross section and increasing its resistance. The object of this bi-metallic wire is to combine great tensile strength with good conductivity, small weight, and cheapness.

The advantages claimed over the phosphor and silicium bronze wires are, that the latter are brittle and will not stand bending or twisting, and that in course of time they become granular or crystalline, and that they are expensive. The object of the bi-metallic wire is to combine the good conductivity of copper with the tensile strength of steel, and at the same time use the copper sheath to protect the steel from the action of the air and water.

The process is not described, being apparently a secret. The two metals are firmly united, as though they were welded.

The weight and diameter are evidently less than that of a steel wire of the same conductivity would be, and it is claimed to resist a greater tensile stress than copper wire. It is claimed to resist perfectly bending and torsion, and that it is quite flexible and elastic. The selling price, for 1 millimeter diameter and over, is given as 150 francs per 100 kilograms, which is equal to about 13 cents per pound.

There is a disadvantage in its use, however, namely, that if the steel should be exposed anywhere, the action of moisture will be to destroy the steel at that place much more rapidly than if it were not covered with copper, because the steel and copper form a short-circuited electric couple the action of which is to decompose the iron and to clean the copper. In galvanized iron wire this electrical and chemical action is just the reverse, as it keeps the iron clean at the expense of the zinc.

Copper-covered iron wire was made in the United States more than a dozen years ago, and for the same object. It was made by electroplating the iron wire with a thick coating of copper. But it was found that the iron wire appeared to absorb in its pores some of the liquid of the bath, which in time destroyed the iron completely by the action described above. All the lines run had to be replaced, and the extensive wire works had to be abandoned. It is presumed, therefore, that the process of Martin is not the same. In one specimen in Martin's exhibit, the steel was 1½ inches in diameter, and the copper three-eighths of an inch thick.

Properties.—The following figures give the results of some tests of the Martin bi-metallic wire. They were made at the Laboratoire Centrale d'Électricité of the Société Internationale des Électriciens: External diameter, 3 millimeters, or between Nos. 8 and 9 B. & S. gauge. Ultimate tensile strength, 388 kilograms, or 55 kilograms per square millimeter; or 78,000 pounds per square inch. (That of copper is about 26 kilograms per square millimeter, or 37,000 pounds per square inch.) Elongation, 28 per cent. Number of times it could be bent through a right angle alternately in opposite directions when held in a vise, twenty to twenty-four. Resistance per kilometer at 14° C., 3.91 ohms, or 6.3 ohms per mile. (That of copper wire of the same diameter is 2.35 ohms per kilometer, or 3.96 ohms per mile. That of an iron wire of the same diameter is 14.05 ohms per kilometer, or 22.6 ohms per mile.)

From these figures the following deductions may be made: Its conductivity is 60 per cent of that of copper, and 360 per cent of that of iron wire of the same diameter. The size of a copper and iron wire of the same resistance would be 2.33 and 5.7 millimeters, or about Nos. 11 and 3 B. & S. gauge, respectively. The weight of the bimetallic wire is given as 62.5 kilograms per kilometer, or 222 pounds per mile. That of the iron wire would be about 200 kilograms per kilometer, or 700 pounds per mile. For the same weight of wire on the poles, the number of lines of the same resistance could therefore be tripled, as compared with iron wire. Or, for the same weight as the iron wire, the size of the bi-mětallic wire would be 5.4 millimeters (between Nos. 3 and 4) and its conductivity increased 3.2 times.

Another test made by the same parties gave the following results: Diameter 1.29 millimeters, or No. 16 B. & S. gauge. Ultimate breaking tensile strain, 84.5 kilograms, or 65 kilograms per square millimeter, or 92,000 pounds per square inch. Number of times it could be bent backward and forward over a bar 10 millimeters (0.4 inch) diameter, fifty to sixty. Resistance, 19.61 ohms per kilometer, or 31.6 ohms per mile. Resistance as compared with copper wire of the same diameter, 66 per cent.

INSULATED WIRES.

Wood insulation.—Fortin-Hermann (French section, gold medal) exhibited an insulated wire, made of a bare copper wire, on which are threaded small, short wooden beads, quite close to one another, the whole being afterwards covered with a lead pipe. It is, therefore, quite similar to an insulated wire made in the United States some six or eight years ago, in which the beads were of porcelain, instead of wood. The porcelain had the advantage that the beads could be made large and have numerous holes, so as to contain a number of wires in the same lead pipe and insulated from one another. In the case of the Fortin-Hermann multiple-wire cables, each wire is first covered with its beads, and these are afterwards bunched and covered with lead, making, however, a rather bulky cable.

The claims are that it is cheap, that the insulation is very high, and that the specific inductive capacity of the wooden beads is much less than that of porcelain, and that therefore the static capacity is very low, being for underground wires even lower than in aërial lines, and as the air inclosed in the lead remains unchanged the insulation and capacity remain unchanged. It is used largely in Paris for underground telegraph and telephone lines, and has given very good results, particularly for telephone lines. The following data (reduced to miles) was given:

Insulation, per mile	megohms..	900 to 6,200
Conductivity, per mile	ohms..	10.3 to 18.8
Capacity, per mile	microfarad..	.068 to .060

Patterson cables.—The Patterson cables, included in the exhibits of the Western Electric Company (United States section, gold medal, for collective exhibit) was, besides tho Okonite exhibit, the only United States exhibit of cables containing many small conductors. They consist of groups of conductors, each covered with two or more windings of cotton or jute, or both, saturated with paraffine, and protected by a pipe made of some composition resembling a lead alloy. This composition is said to withstand the action of the water and gases underground, where lead would be destroyed. It is harder and tougher than lead, without being any less flexible. The space between the conductors and the pipe is filled with hot aërated paraffine, free from any oil, and introduced under pressure, together with carbonic acid gas (CO_2). The almost invisible globules of gas, scattered uniformly through the mass of paraffine, renders it elastic, so that the natural shrinkage of the paraffin in cooling is compensated for by the expansion of these globules, thus preventing the formation of cracks and longitudinal fissures through which water would penetrate indefinitely in case of a break in the pipe. Any flaw or leaking joint in the pipe is detected by the process of filling under pressure. The core may be made in lengths of 1,500 feet and the pipe in lengths of 80 to 140 feet. Another function of the occluded gas is to diminish the specific inductive capacity of the paraffine: it is claimed to diminish it 15 per cent below that of pure solid paraffine, and this, they claim, enables them to use smaller conductors than if gutta-percha or rubber were used. This diminished size is claimed to prevent, to a large extent, troubles from "cross talk," due to the condenser action in the neighboring wires.

The current which leaks through the insulation of a cable has a tendency to produce chemical changes if any liquids are present. High insulation therefore diminishes this action by reducing the injurious current, besides economizing energy. The paraffin used contains no oil which might have traces of acids or alkalies. Their cables vary from one-quarter of an inch to 2 inches in diameter and contain from one to two hundred conductors, in lengths up to 8 miles, and are used for telephone, telegraph, and electric-light service. Some have the conductors twisted in pairs for metallic circuits.

From November, 1881, to June, 1889, they have made cables containing 36,927 miles of conductors, of which 22,313 are underground and of which 36,126 are for telephone, 681 for telegraph, and 120 for electric lights.

Okonite.—The Okonite Company's (United States section, gold medal) insulated wire is too well-known to require description here. No technical data could be obtained from the company. The material, okonite, is reported to be a mixture of India rubber and mineral hydrocarbons. It appears to be placed around the wire in the form of a band with a longitudinal seam, and adheres to the wire very tenaciously.

An expert test made for the jury showed an insulation resistance of 6,800 megohms per kilometer at 8° C. (4,200 megohms per mile), and a capacity of 0.36 microfarads per kilometer (0.58 per mile).

Cobb.—The Cobb Vulcanite Wire Company (United States section, gold medal) exhibited electric light wire insulated with a moderately hard but pliable vulcanized rubber tube, and with or without a lead armor. This tube is made of rubber, the vulcanization of which is stopped before the rubber becomes as hard as the ordinary hard rubber, thus giving a material, the insulating properties of which are like those of hard rubber, and having the additional property of being pliable, so that it may be bent to a moderately small circle without injury to the insulation. The tubing is first made of soft rubber mixed with sulphur; by means of special machinery a seamless lead pipe is made around this soft tubing; it is then vulcanized under pressure by compressing the air in the tube, after which the stranded copper wire is threaded through lengths of about 200 feet of this tube, by means of a long steel needle, which operation is done quite rapidly by means of special machinery. The insulation is remarkably high, averaging for a No. 4 or 5 wire cable between 10,000 and 20,000 megohms per mile, and sometimes even exceeding 30,000. This is probably in part due to the fact that the tube fits the wire loosely and that it is therefore insulated to a great extent by the air between the wire and its insulating tube. This wire has been used in New York and Chicago for underground circuits.

CABLES.

M. Menier (French section, gold medal), one of the principal and oldest French manufacturers (founded 1850), had a very fine exhibit of insulated wires and cables chiefly of rubber and gutta-percha insulation. This firm is one of the principal ones furnishing wires and cables to the French Government (telegraph and war departments). The factory covers 5 acres of ground, employs 400 men, and 1,000 horse power, using about 300 tons of crude rubber and gutta-percha; their business, including rubber goods, amounting to about $800,000 a year.

They exhibited a piece of their river cable laid for the Government, between Havre and Honfleur (on the opposite sides of the mouth of the Seine), 8½ miles long. It was laid in 1877 and is still in good condition. It consists of five wires insulated with gutta-percha, and protected with jute and a double armor of galvanized iron wire.

The underground electric-light cables, which they have made for Paris and other cities, consist of tinned copper covered with three layers of vulcanized rubber, and covered with lead 2½ millimeters (one-tenth of an inch) thick. They claim to be the inventors of the double concentric cables.

Other creditable exhibits of cables were those of the India Rubber and Gutta Percha Company (French section, gold medal) and Fowler & Co. (English section, gold medal).

Henley's Telegraph Works Company (English section, silver medal) exhibited samples of a large number of cables made and laid by them. Some of them were of interest historically. The earliest were: A single conductor cable laid at Ceylon in 1857, 30 miles, weight 66 tons; another in Egypt, in 1857, three wires, 9 miles, and 20 tons; another in Tasmania, 1858, 240 miles, weight 408 tons. They were all of the well-known construction, with a galvanized iron wire armor, covered with a protecting compound.

The Commercial Cable Company of New York, showed a model of a cable in which the armor was made of short steel ferrules, the ends of which were made to fit into one another, the joints being rendered air-tight and elastic by means of thick round rubber rings. The object is to protect it from danger from crushing by ice. The crushing strain is 25 tons.

MISCELLANEOUS.

UNDERGROUND WIRES OF PARIS.

These cables are composed of wires of seven strands twisted together and covered with two layers of gutta-percha, alternating with two layers of Chatterton compound. The cables are formed of 3, 5, 7, or 14 of these stranded wires bunched together, spun over with tarred cotton and covered with three layers, the first of tarred jute, the second of cotton tape impregnated with Norway pitch, and the third of tarred cotton tape wound in the opposite direction to the preceding layer. The diameter of the wire used is from 0.5 to 0.7 millimeter (about No. 24 to 21 B. & S. gauge). The seven wires twisted together and covered as described above, are from 3.5 to 5 millimeters (equal to 0.137 to 0.197 inch). The copper has a conductivity of at least 90 per cent that of pure copper; the resistance is not greater than 20.57 ohms per kilometer (equal to 33 ohms per mile), per square millimeter cross section at 0° C. Those most frequently used have the same resistance as iron wire of 4 and 5 millimeters (0.157 and 0.197 inch, or about No. 6 and 4 B. & S. gauge); that is, about 16 to 9.7 ohms per mile. For these the insulation is over 370 megohms per mile at 24° C. (75° F.) and the capacity is less than 0.48 to 0.40 microfarad.

Some others are covered with lead in place of the three layers of of cotton and tape. These are used in the sewers or tunnels, being merely hung on hooks, while those without lead are put into cast-iron tubes in trenches.

For long underground lines the cables are made like the preceding and are generally of three conductors, of which two correspond to an iron wire of 4 millimeters and the other to one of 5. These are placed in cast-iron tubes in trenches. Sometimes, when there is only one cable, it is covered with an armor of iron wire and simply buried. The Société des Téléphones, Menier, India Rubber and Gutta-Percha and Telegraph Works Company (Paris), all three furnish underground wires for the telegraph department of the city of Paris. For electric light underground cables vulcanized rubber is generally used in place of gutta-percha.

French submarine cables.—The conductor of the submarine cables is made of seven strands of copper wire. This is covered with a layer of Chatterton compound and then with three layers of gutta-percha alternating with two of Chatterton compound. This is covered with two layers of jute wound in opposite directions, over which is then placed the armor of iron wire. For deep-sea cables this armor of iron wire is made of small-sized wires, while for shore ends it is made of large wires. For deep-sea cables the armor is galvanized iron, while for shore ends it is an extra fine quality of iron wire known as "Best-Best" quality. This armor is covered with three layers of bituminous compounds and two of tarred linen wound spirally around it.

The submarine cables used by France are almost exclusively made by the large English companies, namely: The Indian Rubber, Gutta-Percha and Telegraph Works Company, the Telegraph Construction and Maintenance Company, and the firm of Siemens Brothers.

Cable making machine.—The administration of telegraphs of France exhibited a small model of the machines used by them at their factory for making cables. The bundle of insulated wires which are to constitute the cable are drawn slowly through a series of tubes in line with each other. Between the end of each tube and the beginning of the next, a layer of the covering material, be it insulation or armor, is wound around the cable from bobbins secured on a revolving disk concentric with these tubes. As the cable passes through, these coverings are thereby wound around it spirally and in alternately opposite directions. It also passes through tanks containing the liquid coating material and finally through a jet of cold water.

Galvanized wire for the French Government.—The following extract from the "specifications for galvanized wire" for the French Government, 1879, shows the requirements made and the tests to which the wire is subjected.

The iron must be reduced and refined entirely with charcoal, and must be free from scale and other faults. It must be galvanized with pure zinc. Wires of 5, 4, 3, and 1 millimeters in diameter must be able to stand a tension of 650, 440, 250, and 30 kilograms, respectively, with an elongation of not more than 6 per cent. It must resist being wound on a cylinder (size not given) and subjected to a tension of 500, 350, 200, and 22 kilograms, respectively. The wire must resist being secured in a vise and being bent alternately forward and backward through a sharp right angle each way, 3, 4, 5, and 8 times, respectively. It must stand four successive immersions of one minute each in a solution of copper sulphate (1 to 5 parts of water) without being stained. The three larger sizes must stand being wound over a cylinder of 1 centimeter in diameter, and the smaller one over a cylinder of 3 millimeters without detaching the zinc; but the wire will not be held strictly to this test. The wire must be made in France.

In the specifications for 1889 the same conditions were imposed with the following additional requirements: The resistance at 0° C. reduced to a wire of 1 millimeter diameter must not be greater than 156 ohms per kilometer (or about 250 ohms per mile for a No. 18 wire).

Testing.—For testing cables and joints roughly during their manufacture, it appears that the so-called plate or influence machines (Holtz, Wimshurst, Carré, etc.), developing very high tension electricity, are coming into use largely in France. They seem to afford a ready, cheap, and effective means to find whether the cable or joint is good or bad, without, however, enabling the insulation resistance to be measured thereby.

Splices.—The Western Electric Company exhibited some splices of multiple wire Patterson cables, which were said by some French experts to be the finest they had seen. One was of 50 pairs, and others of 125 and 100 wires. The individual splices were distributed spirally over a short length of the cable and afterwards covered with a short piece of lead pipe only slightly larger than the other. They exhibited also some good but somewhat complicated splices for electric light wire cables.

Couplings.—For couplings for splicing wires, see under "Accessories," p. 86.

CONDUITS.

The exhibits of conduits were so few that it may almost be said that this branch was not represented at all. There was only one exhibit in the French section and two in the United States. It is all the more strange that this should be so, because in Europe more than anywhere else underground wires are used.

The explanation is probably that it is considered there such a simple matter to lay well insulated cables in the ground directly, or in troughs of wood or concrete, or in sewers, that there is nothing about it to exhibit. The sidewalks in Paris and many other European cities belong to the streets and not to property owners, and they may therefore be used for such conduits, which overcomes some difficulties, especiallly in Paris where the surface covering is generally pitch or asphalt, which therefore keeps the ground below quite dry.

Another reason why it is less difficult there, is that they rarely use the high potential circuits so common in our arc-light distribution, and lately also in our alternating-current distribution.

Another reason why it is apparently receiving less attention is that there is so little electric-light distribution there, as compared to our cities, that there is no such need for complete and flexible systems.

Postel-Vinay.—The system exhibited by Postel-Vinay (French section) was of special interest to Americans as it differed so radically from our ususal systems. Instead of using expensive insulating coverings of wires which appear to cause so much trouble here, they use bare wires in the conduits and support them on insulators. The wires for great currents are in the form of a twisted cable, and are supported about every 7 feet in cast-iron supports which are secured to the iron cross pieces through the medium of strong porcelain insulators to which they are cemented with sulphur.

The conduits are made of concrete having the iron cross pieces firmly imbedded in their sides. The conduits are covered with slabs of concrete or flat stones the tops of which are only a few inches below the sidewalk. In crossing streets they tunnel underneath the sewers if necessary. An advantage of such a system is that house connections are readily made, and that the capacity of the wires may readily be increased at any subsequent time by merely laying another wire over the other, in the same supports. A good illustration of this system. as well as of other details of a system installed in Paris, will be found in La Lumière électrique June 29, 1889, p. 604.

The Consolidated Telegraph and Electrical Subway Company (United States section. silver medal) exhibited charts and models of their systems in New York City, all of which are familiar to American readers.

The American Indurated Fiber Company (United States section) exhibited samples of their pipes for underground circuits. They are proposed as a substitute for iron and creosoted wooden tubes which have been used largely. In a descriptive circular they make the following statements: "This pipe is made by a patented process from long wood fibers, separated, washed free from all saps and gums, molded while in a pulpy state into the requisite size and shape, and then subjected to great hydraulic pressure. It is then treated and hardened by a chemical process, which renders it strong, hard, and impervious to acids and moisture, absolutely waterproof, proof against decay or corrosion, and practically indestructible. The pipe is supplied in lengths of 5 feet with sleeve couplings, bearing standard pipe thread, so cut that the ends 'butt' in coupling, thus preventing any catch or pocket at the joints. Each length is carefully reamed out to a uniform diameter. The weight of the pipe is one-fifth that of iron, and it is therefore more economically handled. The tensile strength of the pipe is about 11,000 pounds to the square inch, and it withstands all ordinary internal pressures. The pipe will resist over 200° of heat, and will stand more frost than iron pipe."

VIII.—APPLICATIONS OF ELECTRICITY IN MEDICINE AND SURGERY.

General.—The apparatus for the application of electricity in medicine and surgery belongs more properly to the department of medicine and surgery, rather than to that of electricity. No attempt is therefore made here to give either a full summary, or a complete description of the exhibits in this branch, nor to describe them from a medical point of view. The following notes are limited to a mere mention of some apparatus which chanced to come to the notice of the writer, and is treated from the point of view of an electrician merely.

It was a satisfaction to notice from the exhibits, that the use of electricity in this branch appeared to be no longer limited chiefly to the practice of the "quack" doctor, but that it was studied systematically and intelligently, and was fast taking an important place in the intelligent practice of medicine and surgery.

The exhibits in this class were quite numerous, and in a number of cases quite elaborate, the apparatus being very complete and creditably designed for convenience and maintenance. The exhibits were limited almost exclusively to the French section.

Unquestionably the finest exhibit was that of Charles Chardin (French section, silver medal). It was quite large and appeared to be very complete, showing good workmanship, intelligent designing, and in a number of cases considerable ingenuity.

A number of improvements were noticed in batteries for medical and surgical (chiefly cauterizing) purposes, with a view chiefly to reducing the amount of attention, care, cleaning, slopping of the liquid, refilling, etc., and for transportable purposes, to make them as light and small as possible. The more important of them will be found described under "batteries." In quite a number of the exhibits of induction coils for generating the so-called "faradic currents" (which are simply interrupted, high tension, alternating currents of different alternating potentials), it was noticed that the usual rapidly vibrating-hammer interrupter of the primary coil was replaced by a long pendulum-like interrupter, by means of which the interruptions were made quite slowly and regular. An adjustable weight on this pendulum enabled the slowness of the interruptions to be varied between great limits. In another apparatus these "interruptions" were produced by a clockwork and revolving contact.

There were a number of exhibits of high-tension batteries for direct application, as also induction or influence machines for the application of direct high-tension charges. The exhibit of the electrodes and cauteries of many different forms was particularly large and varied.

Bréguet (French section) exhibited a very complete and convenient electrical apparatus designed by Dr. Vigouroux, containing among other things a series of induction coils of different windings, and convenient means for measuring at any time both the potential and the current strength with the same galvanometer. The same maker also exhibited the apparatus of Professor Hayem for registering on a revolving drum the currents used in therapeutics.

For a short description of a bullet probe and induction balance for locating a bullet in a body, see under "telephony," p. 131.

The advantage offered by electrical illumination was made use of in a number of pieces of apparatus. In some a small electric lamp was arranged for internal illumination of cavities, or with a small hand reflector. In the "photophone," attached to the forehead of the operator, or on a stand, a lens was in front and a reflector in back of the lamp, producing a strong, parallel beam of light, the lamp itself being only a small battery lamp.

Another apparatus of interest, though not new in principle, was the ozone generator exhibited in operation by Huguet (French section). The principle is that of Houzeau, namely, that if two parallel plates having metallic coating on their outside surface be charged and discharged in rapid succession, as when connected to the secondary circuit of an induction coil, ozone will be generated in the air space between the plates. The apparatus exhibited is shown in the adjoining cut, Fig. 61, which explains itself. The three concentric cylinders are of glass, the two inner ones having tin foil on one side, as shown. The air, forced in through the tube, passes between the two electrified plates, where it is partially converted into ozone, which is collected and inhaled by the patient. For an illustrated article on this subject see Revue Internationale de l'Électricité, August 25, 1889, p. 133.

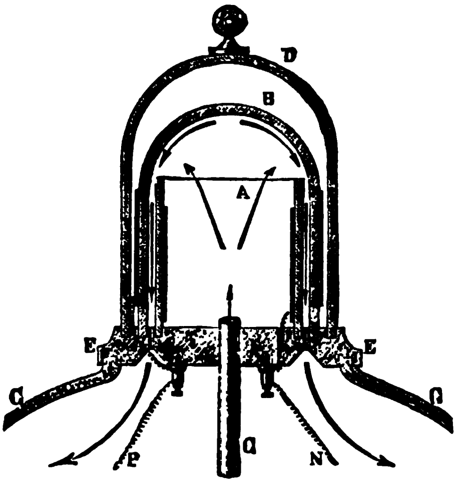


FIG. 61.—Ozone generator; Huguet.

IX.—MISCELLANEOUS EXHIBITS.

LIGHTNING RODS.

Among the half dozen exhibits of lightning rods it was interesting to notice an almost complete change of the general systems, in a diametrically opposite direction, in conformity with the progress of science. In no other class of exhibits was it shown more prominently how the progress of science has, within a short time, almost completely overthrown old and radically wrong ideas which had been adhered to so obstinately for so many years.

In the exhibitions of 1878 and 1881, and doubtless also in subsequent ones, there were exhibits of insulators and holders of various sorts for keeping the lightning rods *insulated* from the building as carefully as possible. In the present exhibition were shown systems and appliances for *connecting* the building electrically as carefully as possible with the lightning rod. The former removes the building as far as possible from the beneficial influence of the lightning rod; the latter, by discharging the house also, protects it as much as possible.

In 1884, when the electrical exhibition building was being fitted with lightning rods on this new and proper system, the "old and experienced" lightning-rod makers (plumbers, we believe) laughed and scoffed at the idea of allowing the rod to be connected to the building and even soldered to the tin roofs. At the present exhibition such makers were, apparently, ashamed to exhibit their former products. In some cases it was noticed also that the intelligent makers used bands and stranded wires to replace the usual solid conductor, in conformity with the recent developments.

In some exhibits, solid, massive, platinum points were used in place of those of brass, platinum plated, on account of the liability of the latter to become fused by a strong discharge, and thereby lose their character of a sharp point, as was shown by samples of actual cases. In another exhibit the maker advocates a lightning-rod tip having a great multitude of points, instead of a few, to facilitate the discharge and distribute it among many points, probably to diminish the liability of fusion of the points.

Milde Fils, & Co. exhibited a complete system showing that they kept pace with all the later developments of science in this branch. They use bands of copper 1¼ by ⅛ inch, tinned on the outside, or, better, iron bands covered with a thick coating of copper which is then tinned, in accordance with the fact lately demonstrated, that the self-induction is less in iron than in copper. Bands are used for this same reason, as also because they can be more readily fastened to the building and bent in conformity with shape of the walls, cornices, etc. The bands are in electrical contact with all the parts of a building, including all water and gas pipes, and have points situated on the tops of every high part. They are fastened, at intervals of about every foot, by improved clamps, which allows them to expand and contract. The earth plates are made of an open spiral, made of 16 meters of this band, which presents a surface of a square meter. This is put into the well. They prefer to have several grounds for each house.

STEEL MAGNETS.

Meritens (French section) exhibited permanent steel magnets of Clemandot made of steel tempered by compression, a process of his own. Magnets of all shapes were exhibited; among them were horseshoe magnets having the following constants:

Weight of magnet.	Greatest lifting force.	Ratio of lifting force to weight.
Kilos.	*Kilos.*	
24.0	100	4
4.5	50	11
1.7	25	15
1.6	33	20

Another exhibit of permanent magnets, that of Marchal (French section), contained some which had the following constants:

Weight.	Lifting force.	Ratio.
0.15	3	20
0.135	3	22
0.025	1	40

MAGNETIC NICKEL ALLOY.

Joseph Wharton (United States section, honorable mention), exhibited bars of nickel, alloyed with various proportions of tungsten varying from 1 to 6 per cent in different samples. This alloy was magnetic to a considerable degree. At the time of writing no figures had been obtained. The nickel is made from nickeliferous pyrrhotite and is about 99 per cent nickel and 1 per cent impurities, chiefly iron.

NON-MAGNETIC WATCH MOVEMENTS.

We believe it has been sufficiently well demonstrated by experiments that a watch will not be affected by magnetism if the hairspring and the escapement are made of a non-magnetic metal. An iron shield around the watch may protect it in a weak field, but it can not, of course, do so in a powerful field, and it is therefore a protection in a degree only. There were a few exhibits of nonmagnetic hairsprings and escapements, all in the Swiss department. Those of

Paillard, already known in the United States, are made of a palladinum alloy. Patek, Phillippe & Co. exhibited hairsprings of an alloy called "mangor," made by Sandoz; also escapements of "woltine" and "wolfor," made by Weidemann. They all have the same appearance as steel; their composition was not given. Some, if not all of them, have other favorable qualities from a watchmaker's standpoint, besides being non-magnetic.

X.—GENERAL SUPPLIES.

CARBONS.

General.—The exhibits of carbon goods for arc lights, batteries, and microphones, and for many other purposes were almost exclusively in the French section. Most of these French exhibits were very creditable, showing great perfection in the manufacture of such goods. They showed not only the possibility, but also the practicability of molding and shaping the carbon in all possible forms and sizes, and giving to it the properties of great elasticity, density, or porosity, as required for different purposes. Rods were shown, from the size of a hair (presumably for incandescent lamps) up to 3 inches diameter and 3 feet long; plates for microphones as thin as paper; delicate spiral springs having very great elasticity; porous cups for batteries; jars for batteries; tubes of all sizes, and delicately molded pieces of complicated forms for various purposes. All of these were made of molded carbon, as distinguished from cut retort carbon or carbonized vegetable material. No information could be obtained about the processes of manufacture, as these are usually kept secret.

Contrary to our usual custom, the arc-light carbons used in France are very rarely copper-plated. This may be due to the fact that their resistance is sufficiently low not to need a copper coating; but it may also, and more probably, be due to the fact that in their usual systems of distribution the arc lamps are connected in multiple arc, and therefore require some dead resistance in circuit to keep the current steadier.

Another custom different from ours is that for the upper or positive carbon of an arc lamp cored carbons are almost universally used. By a cored carbon is meant one which has a thin rod or core lengthwise through the center, similar to a lead pencil; the carbon of this core, being softer than that around it, burns away sooner than the rest, thereby keeping the crater of the arc always in the same position and preventing the arc from traveling around to different sides of the carbon, which phenomenon in the ordinary carbons is one of the causes of flickering and of a blue light on one side of the lamp. The cored carbons appear to cost from 5 to 10 per cent more than the plain, and in addition to this they burn faster, thus increasing the cost of the light somewhat.

The prices of arc-light carbons seem to be exceedingly high abroad as compared with those in the United States; they are from five to ten times as great.

Exhibits.—Among the chief exhibits and exhibitors were the following:

Edmond E. Carré (French section, silver medal) exhibited among other things very complicated forms, molded and cut, chiefly of fine, delicate workmanship; also long, fine, slender tubes.

In the exhibit of Emile L. Lévy (French section, silver medal) were among other things the following: Arc-light carbons 7 feet long and all diameters; a plate about 3 feet by 18 inches by one-half an inch thick; split hollow cylinders of all sizes for batteries; large, hard crucibles, also one of complicated form for an aluminium process; very thin disks for microphone diaphragms; small balls like shot, for microphones; hair-like threads, probably for incandescent lights; a very elastic spiral 1½ inch diameter made of a round carbon rod of about one-sixteenth of an inch diameter.

In the exhibit of Lacombe & Co. (French section, silver medal), which was chiefly of arc-light carbons, were some very large ones 3 feet long and 3 inches diameter; also 5 feet long and 2 inches diameter; also carbon rods with deep spiral grooves longitudinally, the object of which is probably to keep the arc in the center.

Charles R. Goodwin (French section) exhibited porous cups and battery jars of porous and dense carbon respectively. Also very large blocks and slabs probably for batteries.

August Ballat (French section, honorable mention) was the only exhibitor of "cut" or "retort" carbons, or "French" carbons as they are sometimes called in the United Stases. These carbons are very hard and strong, and are cut from blocks, as distinguished from the others, which are molded from a plastic mass and afterwards hardened. The cut carbons are generally preferred for batteries in which strong acids are used, as they last longer and appear to be more porous, thereby presenting more surface to the liquids. The exhibit was a very fine one, showing pieces cut, turned, and carved into numerous shapes and forms, such as rods for lamps, plates, crucibles, dishes, etc. Among the larger pieces was one 4 feet by 1 inch by 3 inches, and a slab 2 feet by 18 inches by three-fourths of an inch, both without a flaw.

Messrs. Mignon & Rouart (French section, silver medal) exhibited carbons for arc lights covered with a hard, black enamel, which they claim increases the time of burning 25 per cent. This enamel is an insulator and must therefore be taken off whenever contact is to be made with the carbon. The carbons are made of charcoal, of coal tar, pitch, and of lamp black. They are very hard, almost metallic, and are claimed to give very little ash. The published prices are quite high when compared to the usual American carbons.

For instance, the price of a seven-sixteenths inch (11 millimeters) plain carbon is 10.5 cents per foot; cored, 11 cents (or 5 per cent more); enameled, 11.5 cents (or 10 per cent more); cored and enameled, 12.1 cents (or 15 per cent more). The usual price or American carbons, seven-sixteenths of an inch, copper plated, but not cored, is 1 to 1.2 cents per foot, or about one-tenth of the above.

The Compagnie d' Électricité et Hydraulique (Belgian section) also exhibited light carbons for which they claim great whiteness of light and an arc without a flame. Their published prices, for the same size as the above, are 5.9 cents per foot plain and 6.5 cents cored.

A price list from an English company gave 3.4 cents per foot for this size, plain, showing that the American carbons are, as a rule, very much cheaper than those in Europe.

A. de Méritens & Co. (French section), who were the pioneers in electric light-house lighting, exhibited carbons for very large lights, which were made of a number of small rods copper plated and afterwards bunched and secured together to form one large rod. They claim that such carbons will point themselves better while burning, and that the flame will "jump" less than with a homogeneous rod of the same size.

The Solar Carbon and Manufacturing Company, of Pittsburg (Bronze medal), was the only American exhibitor. Their carbons are made from mineral oils. No description could be obtained from the makers.

OTHER SUPPLIES.

HARD RUBBER.

The finest exhibits of hard-rubber and gutta-percha goods in the electrical section were those of the Société Générale des Téléphones, and Casassa Fils et C^{ie}. (silver medal), both in the French section. The latter was particularly interesting, showing excellent workmanship and a wide range of adaptability to different forms and uses. Among them were iron jars and other metallic objects like handles, screws, binding posts, etc., covered with a coating of hard rubber adhering to it with great tenacity.

PORCELAIN AND EARTHENWARE.

Among the chief exhibits of porcelain goods for electrical purposes were Hache, Jullien & Co. and L. Thierre, both in French section (bronze medal). There is little to be described about the exhibits, except to mention the very large assortment of different forms of insulators and insulating knobs, tubes, buttons, etc., both for outdoor and indoor wiring; many of the latter forms were very practically designed for facilitating the wiring. Messrs. Woodhouse & Rawson exhibited a very good form of insulator, shown in Fig. 62, which contains a small quantity of oil to insulate the outside surface of the insulator from the supporting pin.

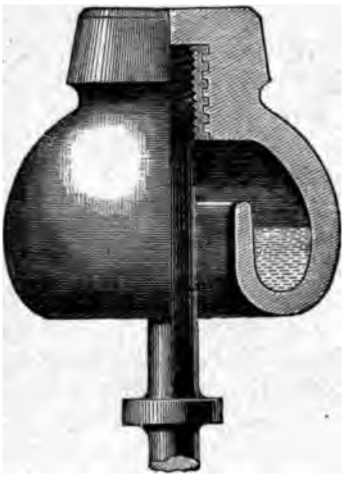


Fig. 62.—Insulator, by Woodhouse & Rawson.

Other novel and ingenious forms of insulators were exhibited by other exhibitors, but they could not be described without illustrations or cuts, neither of which could be obtained.

Fowler, Lancaster & Co. (English section) exhibited a material resembling porcelain, but much better adapted for electrical fixtures. It is hard and strong, and not as brittle as the ordinary porcelain; it can be made with a fine, regular, and sharp screw thread, both inside and outside, which fit together well and smoothly. It can be glazed or colored.

Lallier & Co. (French section, honorable mention) had a creditable exhibit of stone and earthen ware in numerous shapes for different purposes.

FIXTURES.

Among the exhibits of chandeliers, fixtures, globes, shades, etc., were some interesting tulip-shaped shades for incandescent lights, which, from the outside, that is, for transmitted light, had an opalescent appearance with a pink color predominating, while looking at the inside surface, that is, for reflected light, they had the appearance of a bright gilt reflector. They are said to be new, and are known in this country as French shades. Other fixtures, though interesting and numerous, leave nothing to be described.